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Supporting Ambitious Mathematics Practices in the Face of School Reform:
A Case Study of High School Leadership

A Dissertation

Presented to
the Faculty of the Morgridge College of Education
University of Denver

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by

Jacklyn Van Ooyik

March 2021

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Title: Supporting Ambitious Mathematics Practices in the Face of School Reform:
A Case Study of High School Leadership
Advisor: Garrett Roberts
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ABSTRACT

School leaders—both administrators and mathematics leaders—play a critical role in the instructional improvement of teachers in schools. However, current research in mathematics education has not provided a complete picture of the network of administrators, mathematics leaders, and teachers and their roles in supporting ambitious mathematics practices. The purpose of this case study is to examine how ambitious mathematics practices are developed, supported, and sustained within a high school facing pressures for test score improvement and graduation competencies and the roles and responsibilities of school leaders that contribute to that support. In order to address this issue, my primary research question asks: How do the relationships between administrators, mathematics leaders, and mathematics teachers at a large, suburban public high school support change toward ambitious mathematics practices? This research supports the understanding of instructional improvement in mathematics in addition to providing insight into school leaders' support for mathematics teachers; the factors that influence feedback; and mathematics teachers' perceptions of support from school leaders.

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CHAPTER 1: INTRODUCTION

There is an ongoing conflict about what counts as good mathematics instruction in the debate between ambitious instruction, focused on changes aligned with the National Council of Teachers of Mathematics and a back-to-basics traditional curriculum. The roots of these wars can be found in the discussion concerning mathematics for equity versus mathematics as a mental discipline (Schoenfeld, 2004). Traditional mathematics has characteristically high failure rates, functions to keep certain groups from achieving social mobility, and serves the desires of the privileged who benefit from maintaining the status quo (Schoenfeld, 2004). In contrast, ambitious mathematics practices focus on equity of instruction by providing students with opportunities to develop conceptual understanding and participate in all forms of classroom activities (Cobb & Jackson, 2011; Gibbons & Cobb, 2018).

Cobb and Jackson (2011) claim that a focus on instructional improvement has been spurred by educational reform efforts that typically focus on improvement in test scores; however, “it has become increasingly evident that views on what counts as high-quality mathematics teaching matter when formulating strategies or policies for instructional improvement” (p. 8). So as schools face pressure to perform on standardized tests and aim to meet state and federal requirements, it is important to examine how school leaders — mathematics leaders in schools and administrators — develop and support ambitious mathematics practices in schools to meet the needs of all students.

Research Problem and Significance

School Leaders' Roles in Mathematics Instructional Improvement

Cobb and Jackson (2011) outline a theory of action to improve mathematics instruction at scale that includes professional development, networks for teachers, mathematics leaders' practices to facilitate teacher learning, school leaders as instructional leaders in mathematics, and district leaders' practices that support instructional improvement. In addition, a coherent system includes a vision of high-quality mathematics instruction, supports for teacher learning, instructional materials, and supports for struggling students (Cobb et al., 2018). Each of these factors work together and are all critical to sustain instructional improvement; however, all cannot be addressed within the scope of this research project. The primary focus was school leaders' practices to support teacher learning to support ambitious mathematics practices. Facilitating teacher learning involved observing instruction and providing feedback, participating in professional learning communities, and developing relationships with leaders (Cobb & Jackson, 2011). This is discussed further as part of the theoretical framework.

Posamentier (2013) builds on Cobb and Jackson's recommendations by stating that leaders in mathematics should be a resource for best practices in schools. They should be knowledgeable about the current research on best practices in mathematics instruction (Posamentier, 2013). Though research advocates for the use of ambitious teaching methods, traditional instructional practices are still prevalent in schools (Leinwand et al., 2014). Schools should be responsible for providing high-quality mathematics instructional support. This should be made a priority over holding teachers and schools accountable for high-stakes assessment results (Leinwand et al., 2014).

Research is beginning to show that the shared efforts for instructional improvement in mathematics can be beneficial when school leaders and mathematics leaders work together to support teachers' learning (Cobb & Jackson, 2011). However, it is important that these efforts continue to address the goals of instructional improvement while supporting ambitious mathematics practices.

School Leaders' Practices in Mathematics Instructional Improvement

School leader practices can be seen through the lens of sociocultural theory. External factors such as social interactions, can be internalized into mental processes—or internal factors (Eun, 2008). Research highlights that both internal and external factors influence the ability of school leaders to be effective in supporting mathematics instructional improvement. For administrators, internal factors are the most prominent in the literature; this included academic background and beliefs about mathematics. Administrators are often unfamiliar with mathematics instructional practices as many don't have a background as mathematics teachers (Lochmiller, 2016). As a result, administrators provide mathematics teachers with feedback that is general and not mathematically specific (Burch & Spillane, 2003; Lochmiller, 2016; Mette et al., 2015). Furthermore, their beliefs about mathematics instruction are often rooted in their own backgrounds within mathematics; Nelson (2010) refers to this as leadership content knowledge. Often, leaders have beliefs about mathematics instruction that are aligned with traditional mathematics practices; this limits administrators' ability to improve mathematics instruction (Burch & Spillane, 2003; Lochmiller, 2016; Nelson, 2010). External factors for administrators include interactions with mathematics teachers and learning or professional development experiences with mathematics instructional

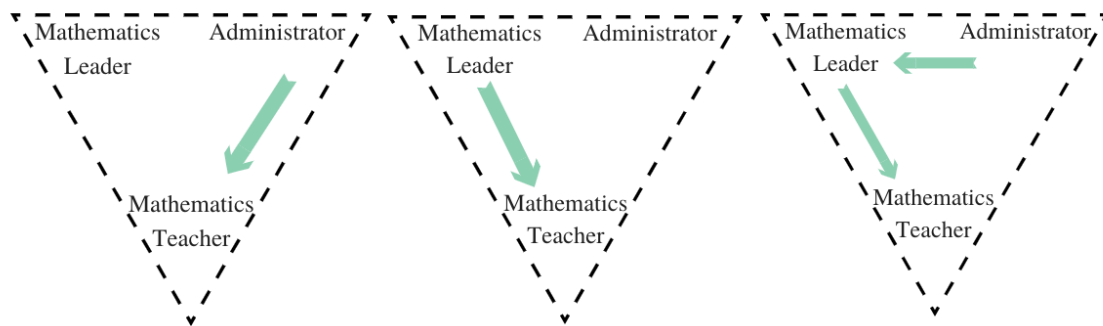
practices. These external factors had the ability to improve the quality of feedback that was given to mathematics teachers (Burch & Spillane, 2003; Rigby et al., 2017).

For mathematics leaders, internal and external factors were discussed in a different context from that of administrators. Researchers often assume that the mathematics leaders (i.e., coaches, department chairs, and instructional leaders) they study have the academic background and mathematical beliefs necessary to support mathematics teachers effectively. Therefore, prior research discussed the actions mathematics leaders engage in—building trust with teachers to help with lessons, conducting team meetings, and providing feedback to improve instruction—more often than their backgrounds and beliefs (Gibbons & Cobb, 2016; Knapp, 2017; Zepeda & Kruskamp, 2007). However, these coaching practices were rooted in mathematics leaders' beliefs about mathematics instruction. Aside from supporting mathematics instruction, there are many other school responsibilities that mathematics leaders are expected to complete: substitute teaching, bus duty, and even making copies (Campbell & Griffin, 2017; Chval et al., 2010; Zepeda & Kruskamp, 2007). These responsibilities are considered external factors and often take time away from supporting teachers in developing ambitious mathematics practices. Another external factor was the impact of administrators on mathematics leaders' work. Administrators can hinder mathematics leaders' effectiveness when these mathematics leaders feel uncertainty about their role in the school (Chval et al., 2010; Knapp, 2017; Zepeda & Kruskamp, 2007). A lack of communication from administrators made mathematics leaders to feel unsupported and confused about how they should best support teachers (Knapp, 2017). Mathematics leaders were most effective in providing support when administrators had open

communication about leaders' work and clear expectations for the position (Mangin, 2007).

Figure 1.1

Current Relationships Explored in the Research



Lack of Research Examining Development of Ambitious Mathematics Practices

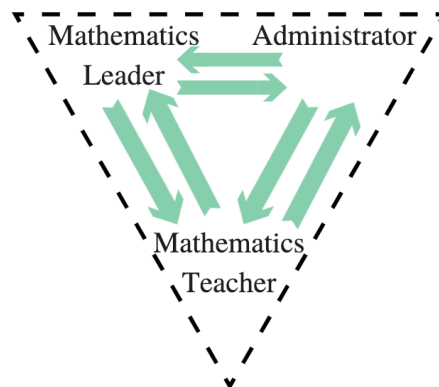
Cobb and Jackson's (2011) theory of action for instructional improvement in mathematics emphasizes that improvement at scale not only involves teacher learning but organizational learning as well. Mathematics teachers need support for their own learning and members from various role groups need to change their practices. Support for ambitious mathematics practices should include mathematics leaders facilitating teacher learning and school leaders as instructional leaders in mathematics (Cobb & Jackson, 2011). Current research examines only isolated relationships between administrators, mathematics leaders, and mathematics teachers (see Figure 1.1). This is a significant gap in the literature because it does not examine instructional improvement through a coherent system.

The model of research should examine the relationships between the administrator, mathematics leader, and the mathematics teacher at the same time. This research model should allow for collaboration and two-way conversation between all

three stakeholders involved (see Figure 1.2). A coherent instructional system needs to be present for improvement at scale and involves both common goals and a system of supports for mathematics teachers (Cobb et al., 2018). In the current literature, these elements are not explored in detail. Additionally, Cobb and colleagues (2003) claim that analyzing the teaching and learning of mathematics are intertwined within the activities of communities of practice. When examining instructional improvement, it is important to use a research model that involves administrators, mathematics leaders, and mathematics teachers because the support that teachers receive can vary by role if a coherent system is not in place. Exploring the dynamic of the network of the three relationships provided a clear understanding of how instructional improvement and the development of ambitious mathematics practices can happen in schools.

Figure 1.2

Relationships That Need Further Exploration in the Research



Note. Arrows indicate a bidirectional relationship.

Theory in Mathematics Education

There are contradictory views about the role that theory should play in mathematics education scholarship: some stress that mathematics education research

should be simply useful to practice while others believe that research should be focused on theory to elevate the status of the field (Silver & Herbst, 2007). Some academics within the field argue that the theoretical focus has hindered the application of research into practice. In contrast, many believe that the gap between research and practice is caused by a haphazard use of theory in communicating the implications for practice. In order to effectively integrate theory to affect practice, theory should exist in the foreground of the relationship between problems, practice, and research by mediating the relationship between the three, illuminating connections that are normally invisible (Silver & Herbst, 2007). For the purposes of my research, I used my conceptual and theoretical frameworks to mediate the relationship between research and practice. The frameworks used served two roles: first, the conceptual framework, ambitious mathematics practices supported understanding “and elaborated in this sense that...theory can be a language of description of an educational practice [and] a conceptual system that may establish the grounds on which the existence of an educational practice is plausible or reasonable” (pg. 56). Second, sociocultural theory as a theoretical framework played a role of prescription “and elaborated that in this sense theory can be...a definition of what that practice consists of that allows it to be visible for the purposes of analysis and inquiry” (pg. 56).

Conceptual Framework

The purpose of my conceptual framework—ambitious mathematics practices—was to clarify the concepts discussed in this study in addition to providing a context for and explain the analysis of findings. Mathematics education literature refers to these practices in various ways, setting them apart from traditional instructional practices in

mathematics. Inquiry-oriented mathematics, reform-oriented mathematics, research-based mathematics, collaborative mathematics practices, and ambitious mathematics practices are all common terms used. For the purposes of my research, I used the phrase *ambitious mathematics practices* to describe these instructional principles as this term has a strong research base. Here, I first discuss traditional instructional practices then highlighted characteristics of ambitious mathematics practices in more detail.

Traditional classrooms are generally characterized in research as possessing the following characteristics: students use standard algorithms to solve problems and find answers (Kazemi & Stipek, 2001); rote-learning and decontextualized problems with a focus on memorization are common (Gutstein, 2003); teacher-centered lessons follow a sequence of direct instruction, guided practice, and independent practice (Sherman et al., 2016); and correct answers to mathematics problems are encouraged (Boaler, 2002). Because of these traditional mathematics practices, Schoenfeld (2002) states that mathematics instruction is failing to meet the needs of many students, particularly students of color and low-income students. Many students aren't able to understand the real-world applications or conceptual, common-sense nature of the algorithms they learn (Freudenthal, 2002). Even when high achieving students approach more advanced classes in mathematics, their conceptual understanding is weak due to a primary instructional focus on procedural fluency (Hernandez-Martinez et al., 2011).

“Students learn to locate themselves within the dichotomies of schooling. They narrate themselves and are narrated by others into storylines of success and failure, competence and incompetence, participant and non-participant, included and excluded, etc.” (Dutro, Kazemi, & Balf, 2006, pp. 25-26). Successful participation in the traditional

mathematics classroom means that students often give up their agency as learners; this is apparent when students describe the expectation to be compliant in mathematics class (Boaler & Greeno, 2015). Students' interactions and participation in mathematics classrooms impact both their mathematical thinking and their ability to persist, their views about competence, and their ability to be successful in school (Franke et al., 2007). These traditional practices hinder students' mathematical understanding because to do not give students opportunities to attend explicitly to mathematical concepts or provide students opportunities to struggle with important mathematics (Hiebert & Grouws, 2007). Because traditional mathematics is a passive and individual activity, it provides students little opportunity to develop an understanding of mathematics that is meaningful and coherent (Boaler & Greeno, 2015).

In contrast, key characteristics of ambitious mathematics practices include a focus on all students to have opportunities for problem solving, cognitively demanding tasks or productive struggle, effectively engaging students in the tasks, supporting groupwork in forming solutions to problems, and orchestrating classroom discussions about learning (Kazemi et al., 2009; Lampert et al., 2010; Lampert et al., 2011; Leinwand et al., 2014; Rigby et al., 2017; Stein et al., 2008). Ambitious mathematics practices support both conceptual understanding and procedural fluency (Hiebert & Grouws, 2007). Yackel and Cobb (1996) discuss these practices in terms of *sociomathematical norms* that specify student activity in a mathematical context, rather than in the general classroom. While all mathematics classrooms have sociomathematical norms, in an ambitious mathematics classroom, the focus of sociomathematical norms is to develop the intellectual autonomy of students. Intellectual autonomy emphasizes the ability for students to be active

participants in the classroom, make mathematical decisions, and contribute in meaningful ways to discussions (Yackel & Cobb, 1996).

Along with intellectual autonomy, Cobb and Jackson (2011) argue that a central component of ambitious mathematics practices is equity in participation of classroom activities, meaning all students should have access to content and the ability to participate in all forms of classroom activities. Effective mathematics programs in schools require instructional practices that engage students in both collaborative and individual experiences that allow students to make sense of ideas and promote reasoning (Leinwand et al., 2014). The goal is that all students develop a productive mathematical disposition—meaning students need experiences that help them realize that they are capable of learning mathematics. Productive disposition increases students’ motivation and their agency as mathematicians. To accomplish this, NCTM (Leinwand et al., 2014) outlines eight principles of mathematics practices including selecting tasks that promote reasoning and problem solving, facilitating discourse, and engaging students in productive struggle.

A strong research base has been built showing how ambitious mathematics is implemented in the classroom. For example, Staples (2007) elaborates on learning practices for a collaborative classroom through her study of one high school mathematics teacher, Ms. Nelson. In order to facilitate collaborative inquiry in her classroom, Ms. Nelson used three areas of practice including “supporting students in making contributions, establishing and monitoring a common ground, and guiding the mathematics” (p. 172). These practices mirror the idea of the role of the teacher as a facilitator of learning where she takes a less active role of teaching and instead provides

structure where students' mathematical work takes place. Ms. Nelson shaped her work from students' ideas and participation. Another example is Boaler and Staples' (2014) case of Railside School where students worked in groups on long, conceptual focused problems. Students at Railside reported more agency in mathematics. The contrast between Ms. Nelson and Railside school, however, is the instructional coherence found at Railside. The goal of ambitious mathematics practices were a department wide goal at Railside where students and teachers alike could learn the mathematics at a deeper level. In contrast, Ms. Nelson was the only teacher pursuing ambitious mathematics practices at her school and as a result, her and her students did not have the same mathematical supports from year to year.

However, both of these studies highlight the need for a deep understanding of mathematics is necessary for implementing ambitious mathematics practices. Staples (2007) shows that, in an ambitious mathematics classroom, a teacher's role shifts from a more traditional role to supporting student contributions, monitoring common ground, and acting as a guide. In order to make this shift, teachers need to understand various student strategies and maintain rigor during discussions. Teachers need opportunities to gain experience in these practices (Staples, 2007). Understanding student strategies and multiple methods of solving problems are referred to as Mathematical Knowledge for Teaching (Ball et al., 2005). Ambitious teaching is hard to implement because it has a demanding set of challenges (Lampert et al., 2011). Instructional resources—such as instructional materials, incentives to collaborate with colleagues, common space, time to address problems of practice, and working toward a common goal—are critical in implementing ambitious teaching. Collaboration among the mathematics department and

school leaders have a stronger potential to support and develop ambitious mathematics practices (Boaler & Staples, 2014; Lampert et al., 2011).

The relationship between research and practice in mathematics is essential in facilitating student learning. It is important to provide direct support in helping teachers and school leaders develop their capacity for these ambitious mathematics practices (Cobb & Jackson, 2012). Leinwand and colleagues (2014) advocate that researchers and school personnel should work together to tackle these issues and implement strategies based on research. Staples's (2007) study is an example of how researchers and practitioners can work together to advance ambitious mathematics practices. Teachers working in isolation to implement ambitious mathematics practices has little effect on student learning or improvement to equitable outcomes for students (Horn, 2008). However, it should be the primary responsibility of school leaders to develop coherent instructional systems within a school (Sharpe et al., 2018). This can be accomplished by providing observation and feedback, coordinating supports for teacher learning, providing opportunities for teacher collaboration, collaborating with coaches, and fostering teacher advice networks (Sharpe et al., 2018).

Theoretical Framework

As discussed, Cobb and Jackson (2011) outline a theory of action for improving mathematics instruction. Facilitating teacher learning involves observing instruction and providing feedback, participating in professional learning communities, and developing relationships with leaders (Cobb & Jackson, 2011). I drew on sociocultural theory as a lens for making these school leadership practices visible for research. Guskey (2000) defines professional development as the practices or activities that build attitudes,

knowledge, and skills of teachers to achieve the goal of increased student learning. He defines four areas of professional development activities including training, observation and assessment, mentoring, and inquiry. My research will focus more on the activities of observation and assessment, mentoring, and inquiry within communities of practice. Eun (2008) states that the goal of professional development is to increase student learning through changing attitudes, knowledge, and skills of teachers. However, in order for professional development to be transformative, it must rely on social interactions. Professional development activities have rarely been grounded by a theoretical framework; however, it is important to illuminate the process of teacher learning to make it visible for the potential development of other effective programs. Theory allows for a deeper understanding of why results occur from the implementation of certain practices. In addition, theory allows for a complex understanding of mechanisms involved in practice and, as a result, contributes to improved professional development programs (Eun, 2008). In this section, I will discuss sociocultural theory in the context of observation, communities of practice, and the role of the organization.

Sociocultural theory examines the process in which individuals develop intellectually through participation in cultural practices (Cobb, 2007). This is underpinned by the work of Vygotsky (1978), who argued that the mind is created through a process of internalization through social interactions. Specifically, this is referred to as mediation, where social interaction is transformed into internal mental functions of the individual (Eun, 2008). Mediation can occur through material tools, symbolic systems, and other human beings (referred to as mentors). The idea of mentoring is linked closely with Vygotsky's idea of the Zone of Proximal Development

(Vygotsky, 1978), where working with a more experienced mentor will lead to transformation and learning. This can be a reciprocal process, where both the mentor and the mentee can change their ZPD. Through the mentoring relationship, both participants have the capacity for transformation. Vygotsky calls this intersubjectivity, where both mentor and mentee gain a shared understanding and reorient their thoughts and behaviors through the interaction. This aligns to the work of school leaders' evaluation or observation within the school system. In an observation or evaluation, the teacher gains feedback in order to support the development of skills that are beyond their practice at the time, which Vygotsky refers to as scaffolding (Eun, 2008). Heineke (2013) also advocates for the use of sociocultural theory when examining professional growth of teachers and teacher coaching. A central theme highlighted in his use of sociocultural theory is how knowledge, identity, and language are co-constructed within a social situation as learning cannot be separated from the setting in which it takes place (Heineke, 2013).

Sociocultural theory also plays a critical role in the idea of communities of practice where learning takes place through negotiation of meaning—the continual participation (membership in social communities) and reification (projecting meanings into the world) to form new histories (Wenger, 1998). Eun (2008) discusses communities of practice as collective scaffolding, which creates an environment in which members are engaged in a collective problem-solving process that is characterized by collective support, with no defined mentors or mentees. This is a common structure for teacher communities, where collaboration among the workgroup results in new knowledge or skills through social interaction. In addition, Wenger (1998) states that participation leads

to the construction of a new identity; an identity that is situated in relation to the community (Wenger, 1998).

Cobb (2007) argues that the organizational structure of the school can impact teachers' development of new instructional practices. The school context must be transformed to be flexible in teachers' efforts at implementing what they have learned in their professional development (Eun, 2008). There should be an understanding that development can include progressions and regressions. School leaders must be able to assess the needs and goals of participants and involve teachers in the planning to achieve those goals. Organizations should allow time for teachers to reflect on and use their new knowledge and skills and within small steps, provide continuous follow up support and time to interact with and discuss with other teachers, and use various models of professional development. The goal of using sociocultural theory as the theoretical framework was to examine the setting in which teachers modify instructional practices. These instructional practices are influenced by the institution, the assistance teachers receive, and the resources available for their classroom practice (Cobb, 2007).

Purpose of the Study and Research Questions

The purpose of this case study was to examine a) how ambitious mathematics practices are supported and sustained within a high school facing pressures of increasing test scores and meeting graduation competencies and b) the roles and responsibilities of school leaders in supporting that change. In order to address this issue, my primary research question asked: How do the relationships between administrators, mathematics leaders, and mathematics teachers at a large, suburban public high school support ambitious mathematics practices? Sub-questions for my study include:

- How do internal and external factors influence administrators and mathematics leaders' support of ambitious mathematics practices with mathematics teachers?
- How do administrators and mathematics leaders provide content-specific coaching to mathematics teachers to support ambitious mathematics practices?
- How do administrators collaborate with mathematics leaders to support ambitious mathematics practices?
- How do mathematics teachers perceive administrators' and mathematics leaders' support of ambitious mathematics practices?

Research Design and Methods

I chose the research site, a high school in a suburban area outside of a metropolitan city in the western United States, because the mathematics department has worked to implement ambitious mathematics practices for the past several years. In order to explore the extent to which and how school leaders support ambitious mathematics practices with high school mathematics teachers, I examined the interactions between high school mathematics teachers, administrators, and mathematics leaders in both formal and informal evaluation settings at the high school. I collected multiple sources of data including observations of classrooms, department meetings, professional development activities and coaching or evaluation conversations; interviews of teachers, mathematics leaders, and administrators; and relevant artifacts and documents. In order to analyze the data, I followed Saldaña's (2016) methods of first and second cycle data coding. Finally,

I incorporated naturalistic generalization (Creswell, 2013) to gain an in-depth idea of the case and to make explicit what can be learned from it.

Table 1.1

Research Question, Data Source, and Analysis

<u>Proposition/Literature Findings</u>	<u>Data Collection</u>
How do the relationships between administrators, mathematics leaders, and mathematics teachers at a large, suburban public high school support ambitious mathematics practices?	Teacher Interviews Leader Interviews Observations Participant Observations Documentation/Artifacts
Sub-Question 1: How do internal and external factors influence administrators and mathematics leaders' support of ambitious mathematics practices with mathematics teachers?	Leader Interviews Participant Observations
Sub-Question 2: How do administrators and mathematics leaders provide content-specific coaching to mathematics teachers to develop ambitious mathematics practices?	Teacher Interviews Leader Interviews Observations Documentation/Artifacts
Sub-Question 3: How do administrators collaborate with mathematics leaders to support ambitious mathematics practices?	Leader Interviews Observations Participant Observations
Sub-Question 4: How do mathematics teachers perceive school leaders' support of ambitious mathematics practices?	Teacher Interviews Participant Observations

Significance of the Study

Describing and interpreting the relationships between school leaders and mathematics teachers at a high school supporting ambitious mathematics practices

enhances understanding of instructional improvement in mathematics. My study contributes to the literature by addressing administrator support for mathematics teachers and mathematics leaders; mathematics leaders' support of mathematics teachers; the factors that influence feedback; and mathematics teachers' perceptions of support from school leaders. This research is relevant to school leaders who are interested in supporting and developing ambitious mathematics practices with mathematics teachers. The goal of a single case study is to provide a potential model of success with supporting ambitious mathematics practices in schools in addition to encouraging future research into the development of these practices in other settings.

Summary

Traditional teaching practices in mathematics continue to persist in schools even though evidence highlights that these practices are not equitable (Schoenfeld, 2004). In order to make instructional improvements in mathematics, more research is needed that examines how mathematics leaders, administrators, and mathematics teachers work together to support and foster ambitious mathematics practices. My study examined these relationships at the high school, as they have been working to implement these practices. In the next chapter, I review the literature on school leaders and mathematics teachers. In the third chapter, I describe the study design.

Definition of Terms

Administrators: the subset of school leaders that includes assistant principals and principals.

Ambitious mathematics practices: mathematics instruction, based in research that is the opposite of traditional teaching practices. Ambitious mathematics practices

include practices like cognitively demanding tasks, supporting groupwork, and orchestrating classroom discussions. Furthermore, the aims of ambitious mathematics practices are to engage all kinds of students in authentic problems in mathematics.

Content-specific coaching activities: practices that relate specifically to administrators and mathematics leaders work with mathematics teachers. Leaders who engage in coaching activities should be knowledgeable about instructional practices and support the development of ambitious instructional practices (Gibbons & Cobb, 2018). Productive coaching activities include building trust, providing resources, and sharing professional learning. However, the most important activities include co-teaching, modeling, and debriefing after an instructional observation. Co-teaching is when the coach partners with a teacher in a classroom to provide suggestions throughout the course of a lesson. Modeling is watching a more experienced colleague. And finally, observation is when a coach observes a lesson and debriefs the conversation. All of these can provide opportunities for teachers to learn as well as problem solve and develop solutions for practice (Gibbons & Cobb, 2018).

Distributed leadership: the presence of a mathematics leader or multiple mathematics leaders at a school to provide more content-specific leader practices for mathematics teachers with the goal of improved instructional practices (Cobb & Jackson, 2011).

External factors: builds on Vygotsky's ideas about internal and external scaffolding within sociocultural theory (Eun, 2008). External factors are activities and social interactions within a culture.

Internal factors: are external factors that have been internalized through the process of mediation and are now part of one's mental functions and processes (Eun, 2008).

Mathematics leaders: the subset of school leaders that includes instructional coaches, mathematics coaches, and department chairs.

School leaders: general term that encompasses both administrators and mathematics leaders.

CHAPTER 2: LITERATURE REVIEW

Background and Rationale

The purpose of this literature review is to examine extant research surrounding the role that school leaders play in the development of ambitious mathematics practices in classrooms. I begin by providing an overview of previous syntheses within this area. Next, I describe my systematic literature review including the search procedures. Then, I identify themes from the literature related to the relationship between administrators and mathematics teachers, mathematics leaders and mathematics teachers, and mathematics leaders and administrators. Finally, I discuss the implications of these findings and areas of future research which I further articulate in the methods section (chapter 3) of this proposal.

Kraft and colleagues (2018) provided a meta-analysis (quantitative) of the effects of teacher coaching on instruction and achievement, the specific coaching programs that provide larger effects, and the relationship between coaching programs with instruction and student achievement. The authors searched seven databases and included articles that were published prior to 2017. Articles were included if they evaluated a professional development program that included a component of coaching, used a sample from early childhood to 12th grade in the United States, used an experimental or quasi-experimental design and used at least one measure of classroom instruction. Sixty studies were included in the meta-analysis, however, only two studies addressed mathematics

specifically. A majority of the studies looked at coaching for reading. This meta-analysis found strong effect sizes of coaching on teacher instruction but the authors' ability to make inferences about student achievement was limited as a majority of studies used reading assessments as a measure of outcomes. Their findings also indicated that little is still known about content-specific coaching programs and the coaching activities used in these programs. Finally, content-specific coaching has not been examined extensively outside of reading and literacy. Additionally, there is little research on how coaching affects different subject areas and teachers with varying levels of experience (Kraft et al., 2018).

Luebeck and Burroughs' (2017) synthesis of mathematics coaching aimed to take a journey through mathematics education scholarship in a variety of different forms of research design in order to illuminate various studies for other researchers. This included overviews of perceptions of coaching, definitions of coaching, investigations of coaching, and observations of coaching. However, this was not a systematic search of the literature. This is a major limitation as key research might not be represented in this synthesis. Nevertheless, the authors found that a variety of external factors affect coaching effectiveness: building long term roles for coaches as mathematics experts and interpreters of research, developing strong relationships, and providing strategies to support teacher learning. Furthermore, they identified several positive effects of coaching on instruction. They claim that more research is needed on the relationships between content knowledge and coaching, the relationship between coaching and teaching, and between coaches and school leaders. Specifically, it is recommended to look into how administrators better support the goals of mathematics coaching and how coaches should

navigate the space between teachers and administrators. Finally, these authors advocate for making research instruments for mathematics coaching more widely available to continue to improve the area of research (Luebeck & Burroughs, 2017).

Literature Review Purpose

My literature review builds on these prior two syntheses and improve on the weaknesses of both. First, this is a systematic review that includes both qualitative and quantitative studies. It also focuses specifically on coaching for mathematics teachers as Kraft and colleagues (2018) included only two out of 60 studies that addressed mathematics specifically. Finally, both prior syntheses call for more research in the area of administrators working with mathematics leaders and how mathematics leaders work with teachers to improve instruction. Therefore, the purpose of my literature review is to provide a research basis for mathematics coaching through examining the impact of the relationships between administrators, mathematics leaders, and mathematics teachers. Specifically, I seek to identify how these relationships can lead to improved instructional practices in mathematics. My literature review adds to the two prior syntheses described by addressing mathematics specifically, using a systematic search process, and using both qualitative and quantitative studies.

Literature Review Search Procedures

In examining the coaching mathematics teachers receive from school leaders, I completed a systematic search of peer-reviewed literature between 1998 and 2018 using ERIC and PsychINFO. I used the following terms: (math*); and (coach*, lead*, supervisor, evaluate*, or specialist); and (teacher, educator, principal, administrator, or student). The following criteria guided the inclusion of literature sources:

1. The study examined coaching or evaluation of K-12 mathematics teacher instruction by school or district-hired personnel.
2. The level of analysis included students, teachers, or school leaders.
3. The study took place in the United States and articles were written in English.
4. Articles described empirical studies including qualitative, quantitative, and mixed methods studies.

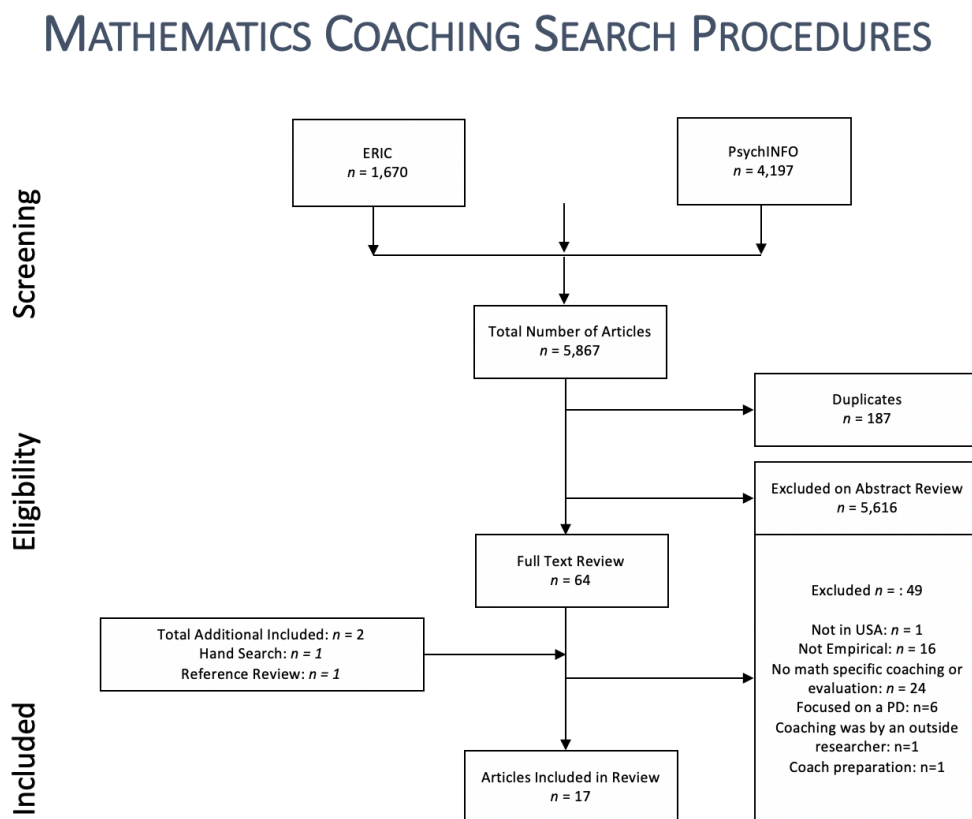
I excluded articles if they focused only on a professional development component for mathematics teachers; I wanted to focus specifically on coaching activities for mathematics teachers. Second, I excluded articles if the coaching involved preservice teachers, to focus specifically on in-service mathematics teachers. Finally, I excluded articles if an outside leader or researcher completed coaching or feedback. I did include articles that included a district hired mathematics leader, but they had to work within a single school full time. These exclusion criteria allowed me to focus on consistent relationships between school leaders and mathematics teachers.

I completed the initial search along with another Ph.D. student which yielded 5,867 articles from the given search criteria. After an initial examination and abstract review, 64 articles were identified for further examination and 15 articles met the inclusion criteria. Next, two relevant literature reviews were searched (Luebeck & Burroughs, 2017; Kraft, Blazar, & Hogan, 2018) to identify any additional relevant articles resulting in one additional article (Mudzimiri, Burroughs, Luebeck, Sutton, & Yopp, 2014). Following, I completed a hand search of the journals that yielded articles in the initial search. The following journals were searched from 2014-2018: *Elementary School Journal*, *Education Administration Quarterly*, *New England Mathematics*

Journal, Journal of Mathematical Behavior, High School Journal, Journal of Education, Education Leadership Review, and Journal of Personnel Evaluation in Education. In addition to these journals, I completed an additional hand search from 2014-2018 Of the *Journal of Mathematics Teacher Education, Journal of Research in Mathematics Education, American Education Research Journal, and Journal of Teacher Education* as these are key journals in my area of interest that didn't yield results in my initial search. No additional articles were found (See Figure 2.1).

Figure 2.1

Overview of Mathematics Coaching Search Procedures



I read and coded each article for research method and findings. Results from each article were then grouped by theme. From the identified 17 studies, seven studies were in

elementary school, five were in middle school, two were in high school, and three spanned across school levels. Fourteen studies employed a qualitative design, one was quantitative, and two used a mixed methods approach. The unit of analysis varied; for example, studies focused on multiple schools and hundreds of teachers, a small group of administrators, and one teacher and coach. I coded each article for research method and grouped findings into three areas: administrator and teacher relationships, administrator and coach relationships, and coach and teacher relationships. Table 1.1 shows an overview of each article included in the literature review, the research methods used, the main findings, and what themes are addressed in the research.

Administrator/Mathematics Teacher Relationships

This literature review begins with examining the coaching relationship between administrators and mathematics teachers. This section discusses administrator activities as observing teachers within classrooms and providing feedback about instruction during both pre- and post-observation conferences. Administrators are defined as principals or assistant principals; however, most of the articles refer to this group in general terms of administrators. I found that school administrators had both internal and external factors that influenced their observations and feedback of mathematics teachers. Internal factors include the beliefs and backgrounds within mathematics teaching, defined as Leadership Content Knowledge, and the second, leadership experience. External factors included interactions with mathematics teachers and professional development activities. A majority of the articles discussing this relationship provide a critique on the lack of content-specific feedback that is provided by administrators to mathematics teachers.

Table 2.1*An Overview of the Literature, Research Methods, Findings, and Themes*

<u>Study</u>	<u>Research Methods</u>	<u>Findings</u>	<u>Admin/ Teacher</u>	<u>Admin/ Leader</u>	<u>Leader/ Teacher</u>
Burch & Spillane (2003)	Case study of administrators at eight elementary schools.	Leaders' strategies were shaped by their views of the subject matter and frequency of interactions with teachers.	x		
Campbell & Griffin (2017)	Quantitative data collection of surveys of 21 elementary mathematics coaches.	There was variance in the amount of coaching and the types of coaching activities for elementary school teachers.			x
Chval et al. (2010)	Case study of 14 K-Seventh grade mathematics coaches.	For new math coaches, their role was shaped by identity and relationships with teachers and principals.		x	x
Ellington et al. (2017)	Mixed methods study of middle school mathematics coaches and teachers from ten school districts.	Math coaches had different demands and resources which affected the support they provided to math teachers.			x
Gibbons & Cobb (2018)	Case study of one coach and seven middle school math teachers.	The math coach effectively assessed instruction and designed activities to support learning for teachers.		x	

Hartman (2013)	Case study of one new math coach working with fifth to eight grade teachers.	For the math coach in a rural school, trust, insider status, identity, and resistant teachers influenced the coaching role.	x	x
Hopkins et al. (2016)	Mixed methods study of four elementary math coaches and teachers.	Math coaches supported math teachers in implementing new curriculum but were influenced by school and district leaders.	x	x
Kerrins & Cushing (2000)	Case study of six novice and five expert administrators observing a seventh-grade lesson.	Feedback from administrators focused on general feedback, was based on their past experience, and used assessment to be more relevant to teachers.	x	
Knapp (2017)	Autoethnography of a middle school teacher leader.	The leader was hindered by confusion about the leadership role, space between teachers and administrators, and a lack of communication.	x	x
Lochmiller (2016)	Case study of teachers and administrators at five high schools.	Feedback from administrators focused on general feedback, was based on their past experience, and used assessment to be more relevant to teachers.	x	
Mangin (2007)	Case study of elementary administrators, math coaches, and district supervisors from five school districts.	Administrators' knowledge of leader role, interactions with leaders, and support or communication can influence teacher leaders' work.	x	

Mette et al. (2015)	Case study of teachers at eight elementary schools.	Discussing student engagement and allowing for self-reflection influenced an administrator's effectiveness.	x		
Mudzimiri et al. (2014)	Case study of seven elementary school coaches.	The roles and responsibilities of math coaches varied significantly as various duties arise throughout the day based on administrator and teacher needs.			x
Nelson (2010)	Case study of two elementary and middle school principals derived from an LCK survey.	What principals believe about math instruction influences what they observe and how they support math teachers.	x		
Neuberger (2012)	Case study of one third/fourth grade teacher and math coach.	Beliefs about math teaching new practices developed as the result of working with a coach.		x	
Rigby et al. (2017)	Mixed methods study of middle school administrators and teachers in four school districts.	Administrator press was not specific to math and was focused on more general instructional practices.	x		
Zepeda & Kruskamp (2007)	Case study of three high school department chairs.	Chairs experienced ambiguity of their role as instructional supervisors and felt constraints with time.		x	x

Internal

Four studies discussed the internal factors that affect the feedback and observations from administrators which was divided into two categories: Leadership Content Knowledge (Nelson, 2010) and experience brought to their role (Kerrins & Cushing, 2000; Lochmiller, 2016; Mette et al., 2015).

Leadership Content Knowledge. According to Nelson (2010), administrators' knowledge and beliefs about mathematics instruction (leadership content knowledge) influence their level of support when supervising or observing teachers. Nelson advocates that principals should play a critical role in helping teachers develop their mathematical knowledge for teaching. However, many administrators believe that students learn mathematics content best when demonstrating procedures and having time to practice these procedures (Nelson, 2010). These beliefs are not in alignment with the ambitious mathematics practices because these practices aren't giving students opportunities for problem solving, discourse, and productive struggle. Traditional beliefs about mathematics instruction held by principals are rooted in their own beliefs and experiences and impact the feedback and supports they provide to mathematics teachers (Nelson, 2010).

Nelson (2010) found that a principal's leadership content knowledge (LCK) in mathematics influences what they notice when observing classrooms, how they interact with teachers during post-observation conferences, and what they discuss in these conferences. She profiled two principals based on their scores from an LCK survey. One principal with a high LCK score was mathematically specific when observing and was able to articulate student understanding in the subsequent post-observation conversations

with teachers. When observing classrooms, she focused on students' mathematical thinking through examining how the teacher created tasks that supported conceptual understanding and how the teacher responded to their thinking by asking questions. In the post-observation conference, she asked about the central mathematics ideas of the lesson and had an open discussion about students. In contrast, the coach with a low LCK score focused heavily on whether the lesson and materials were aligned to the objective while observing mathematics teachers. He discussed the extent to which general instructional strategies were present but was not math specific in the post-observation conference. Furthermore, he did not connect these practices back to student understanding (Nelson, 2010). These types of low-LCK practices are a common theme in the literature since many administrators don't have a background in mathematics instruction (Burch & Spillane, 2003; Lochmiller, 2016; Mette et al., 2015). As Nelson illuminates, leadership content knowledge can impact the feedback and observations of mathematics teachers.

Experience. Both experience in mathematics as well as experience in an administrative role can impact feedback to mathematics teachers (Lochmiller, 2016; Kerrins & Cushing, 2000). Administrators' feedback to teachers is influenced by their own experiences in teaching and content area expertise, particularly when their content area is not math or science (Lochmiller, 2016). When surveying mathematics and science teachers at multiple high schools about the feedback they received from administrators, Lochmiller found that these teachers did not find administrators' feedback as relevant. The feedback tended to focus on general instructional practices and discussed classroom management and basic pedagogy instead of being content-specific. Good teaching is often seen as universal; however, there are differences between subject areas that are

important for leaders to recognize (for example, sequencing of students' ideas or the use of questioning strategies in mathematics classrooms). Teachers viewed administrators' understanding of content as important to providing specific feedback on their pedagogical practices. Even when leaders have a strong background in mathematics, their feedback is not always seen as helpful if they have been out of the classroom for a significant amount of time or if they do not spend time interacting with the mathematics teachers or the mathematics department at their schools (Lochmiller, 2016).

Experience as an administrator also impacts the types of feedback given to mathematics teachers. Kerrins and Cushing (2000) studied both expert and novice principals' feedback on a seventh-grade mathematics lesson over videotape. Principals watched the same video twice and gave feedback. Novice principals identified the strengths they saw in the lesson but did not give any supporting information with their comments. In contrast, experts skipped the positive comments all together and focused on areas of improvement. Novices were also much less comfortable making evaluative comments and less confident in an evaluative role. They focused mostly on observations of teaching and gave a description or list of ways to improve management. Experts focused more broadly on the lesson and worked to understand the connections between the parts of the lesson and its coherence. They provided more detailed answers but did not try to over- or under-interpret what they saw. Experts' comments focused on student learning and understanding and how the components of the lesson were connected to student learning. This study shows that there are qualitative differences in the supervision of mathematics teachers that varies by experience. Variability impacts the supervision and development of mathematics teachers (Kerrins & Cushing, 2000).

Regardless of their background, administrators wanted to give better supports for instruction, and discussions about assessment data was one way that administrators tried to provide better and more specific feedback to teachers (Lochmiller, 2016). Mette et al. (2015) found similar results when examining pre- and post-observation conferences between administrators and mathematics teachers. Mathematics teachers reported that administrators discussed student assessment issues most during pre-observation conferences. In post-observation conferences, administrators identified performance strengths most and discussed areas of improvement the least. Administrators were rated as more effective by teachers when they discussed how students will be engaged during the lesson during the pre-observation conference and when teachers had the ability to self-reflect about teaching during the post-observation conference. Both findings were highly significant in this study (Mette et al., 2015). This shows that teachers wanted discussion related to mathematics content and student engagement from administrators. In summary, leadership content knowledge and prior experiences of administrators played a role in the types of feedback given to mathematics teachers. Specifically, a predominant theme found in the literature for this section illuminated the problem of administrators' lack of content specific feedback.

External

Nelson (2010) claims that administrators have the ability to increase their leadership content knowledge and improve their own knowledge of mathematics through learning about effective practices, observing mathematics classes taught by experienced teachers, and interactions with mathematics leaders. These are considered external factors, as they are scaffolded through social interactions and tools and have not yet been

internalized (Eun, 2008). Two articles found addressed external factors of learning (Rigby et al., 2017) and interactions with mathematics teachers (Burch & Spillane, 2003).

Learning About Effective Practices. One article highlighted a professional development for administrators on providing feedback for mathematics (referred to as “math press” or “press” in this article) in districts that supported ambitious instructional practices (Rigby et al., 2017). District representatives supported administrators to learn how to provide effective math press for teachers. However, even with providing professional development to administrators, 82% of teachers reported that press from administrators was focused on classroom management and organization (not mathematics-specific) and only 1.8% of teachers reported that administrators discussed issues related to mathematics. In order to support teachers in developing ambitious instructional practices, teachers need press that is related to mathematics teaching. Only four of the principals gave lesson-specific math feedback frequently. These four all had more exposure to the mathematics curriculum and participated in the professional development offered by the district. However, other principals were given similar exposure but did not change their feedback (Rigby et al., 2017). This shows that professional development to support administrators in developing knowledge of mathematics specific feedback is not always effective.

Interactions with Teachers. Administrators’ involvement with teachers impacted their views about needed teacher supports. Those who were less involved with mathematics instruction did not see the need for supports beyond the textbook or basic staff development (Burch & Spillane, 2003). Fifty-seven percent of the administrators in Burch and Spillane’s study at the elementary level had limited interactions with

mathematics teachers while 57% also reported that they had daily interactions with literacy teachers. Fifty-three percent of administrators believed that it was important for teachers to follow the mathematics curriculum closely and many believed it was important to seek outside expertise for training in mathematics. They saw mathematics as a “highly-defined discipline” and believed that external supports were necessary to support the improvement of instruction. In contrast, 80% saw the primary expertise for literacy instruction within their schools. When administrators had more interactions with mathematics teachers, they were more likely to see the need for teacher input and the value of teacher expertise with mathematics instruction, rather than bringing in outside resources for support (Burch & Spillane, 2003). Interactions with mathematics teachers are important to help administrators understand mathematics content and the needs of teachers — in this case greater teacher input and more content-specific coaching in mathematics.

Summary

Within the articles addressing the relationships between mathematics teachers and administrators, both internal and external factors were found to influence the types of feedback given by administrators to mathematics teachers. The articles in this section were all case studies, except Rigby et al. (2017) which was a mixed methods study. Sample sizes in these studies varied but they highlighted that in general, mathematics teachers don't receive mathematics specific feedback from administrators and many teachers felt this was important. In addition, when observing, many administrators looked for general teaching practices during observations. Without mathematics specific coaching and feedback, schools are unlikely to begin the work of developing ambitious

mathematics practices. One way that schools have tried to provide better supports for mathematics teachers is through hiring mathematics leaders. I describe the literature on mathematics coaches and the relationship with teachers in the next section.

Mathematics Leader/Mathematics Teacher Relationships

Distributed leadership has been defined as both a role and a practice in which individuals hold formal or informal roles within the school and are able to provide better supports for instructional improvement (Hopkins et al., 2017). One example of distributed leadership is the role of mathematics leaders in schools who aim to provide more content-specific mathematics support for teachers. Therefore, it is important to examine the relationship between mathematics leaders and mathematics teachers. The literature discusses various titles for the mathematics leader role including mathematics coach (Mudzimiri et al., 2014), teacher leader (Knapp, 2017), mathematics specialist (Ellington et al., 2017), and department chair (Zepeda & Kruskamp, 2007). I have chosen to use the term mathematics leader as it encompasses each of these roles. For mathematics leaders, internal and external factors were discussed in a differently than administrators. Researchers assumed that the mathematics leaders chosen for study have the academic background and mathematical beliefs necessary to support mathematics teachers effectively. Therefore, internal factors were discussed as a set of actions mathematics leaders engage in that are rooted in mathematics leaders' beliefs about mathematics instruction. External factors were prominent in the discussion, addressing the various roles that mathematics leaders play and coaching practices that improve instruction. Therefore, I discuss external factors first then the outcomes of mathematics leaders for teachers and students.

Variation in Duties Performed by Mathematics Leaders

Unlike administrators who were predominantly responsible for observing teachers and providing feedback during pre- and post-observation conferences, mathematics leaders' roles were more extensive and varied with regard to school-wide responsibilities. Five articles discussed these responsibilities (Campbell & Griffin, 2017; Chval et al., 2010; Ellington et al., 2017; Mudzimiri et al., 2014; Zepeda & Kruskamp, 2007). Mudzimiri et al. (2014) found that mathematics coaches were expected to have a large skill set and enact many roles in the school. Mathematics coaches' duties fell under three main areas: classroom coaching cycle related activities, other coaching activities, and administrative activities. Specific tasks that fell under these three activities included designing professional development, facilitating lesson studies and book studies, writing proposals and reports, curriculum development, supporting school driven initiatives, providing resources to teachers, monitoring students, and substitute teaching (Mudzimiri et al., 2014). Department chairs performed similar duties including paperwork, collecting materials and documents from teachers, ordering materials, substitute teaching, and inventorying department materials (Zepeda & Kruskamp, 2007). Many mathematics coaches performed administrative duties, were liaisons for the mathematics department, planned math night, called parents, substitute taught, supervised field trips, cleaned the cafeteria, and made copies (Chval et al., 2010).

In a survey of 14 mathematics coaches, Campbell and Griffin (2017) found variations in the amount of time mathematics coaches spent on tasks both within and across school districts. An average of 13-14 hours per week were spent on tasks unrelated to coaching. Bus duty averaged about two hours of the week, 10 hours per week were

spent working with teachers and 4.5 hours per week was spent preparing to coach. Many coaches reported that they worked outside of the contract time on coaching activities and supporting the school's math program. In a two-year study with beginning coaches, coaches reported spending less time on coaching activities in year two compared to year one. The authors attributed this to experience and thus the ability to execute coaching tasks more efficiently (Campbell & Griffin, 2017). Ellington et al. (2017) conducted a similar quantitative study in which mathematics specialists from ten school districts tracked their activity in an activity log. They found that only 0.62% of coaches' time was devoted to delivering workshops and professional development and, in some cases, they were also assigned teaching responsibilities. In the first year of the study, this accounted for 6.6% of the time and increased to over 10% in the second year. Specialists also reported spending time preparing to coach which included looking for teaching ideas, reviewing lesson plans, and gathering materials. These articles highlighted the various duties that mathematics leaders are expected to perform within the schools that are not always related to supporting teachers. However, many articles discussed the positive practices that are enacted by mathematics coaches in supporting teachers which I highlight in the next section.

Exemplar Coaching Practices

In contrast to the critiques provided in the literature with administrators, there were several positive examples of mathematics coaches' instructional support of mathematics teachers. Case studies of exemplary mathematics coaches described specific supports for teachers, developing trust, and providing feedback.

Co-Teaching and Modeling. Several articles (Chval et al., 2010; Ellington et al., 2017; Gibbons & Cobb, 2016) highlighted co-teaching or modeling as a strategy where mathematics coaches were able to address a specific instructional goal by teaching alongside a teacher. Half of the teachers in Gibbons and Cobb's (2016) study indicated that co-teaching helped improve instruction. Co-teaching a lesson was the most common coaching activity found in Chval and colleagues' (2010) study of first year mathematics coaches; however, not much time was spent planning and debriefing the co-teaching experience. In Ellington and colleagues' study of mathematics specialists' activities, specialists in this study spent an average of 17.5% in year one and 16.8% in year two on coaching specifically. Ellington and colleagues described the coaching activities of two mathematics specialists who spent more time coaching teachers than the other specialists in their study. One mathematics coach modeled lessons and helped teachers make lesson adjustments to fit their individual teaching styles. She also helped one teacher adapt lessons for students with challenging behaviors and the teacher shifted her method of teaching mathematics through the coaching relationship. The second coach in this case study worked with the sixth and seventh grade teachers in remedial math, leading classroom discussions. This coach also supported teachers by providing "go to" lesson plans and supported teachers in implementing the lessons in their classrooms (Ellington et al, 2017). Co-teaching and modeling have the potential to support teachers in developing ambitious mathematics practices by supporting in leading discussions and planning new lessons.

Grade Level Meetings. Knapp (2017) and Ellington et al. (2017) described how mathematics leaders scheduled grade level meetings where they discussed testing,

analyzed student test scores, developed activities for teachers to implement in their classrooms, shared ideas for instruction, and engaged teachers in mathematics lessons. Knapp referred to these as communities of practice. They provided important opportunities to discuss teaching practices and provide common experiences to foster learning and discussions. Intentional planning connected the teachers' individual work to the work of the team. Building trust was also essential for these meetings; the coach created a space that valued authentic conversations and honesty where teachers are able to share stories from and questions about their classroom instruction (Knapp, 2017). Two mathematics coaches highlighted in Ellington et al. study spent more time in team meetings than other coaches. Like the coach in Knapp's study, one coach highlighted spent team meetings supporting teachers in taking turns to share ideas, activities, or leading a lesson exploration. The coach didn't lead these discussions but was able to offer supports throughout the conversation, and teachers were engaged (Ellington et al., 2017). In both of these examples, team meetings were a way for teachers to share teaching practices or lesson explorations to improve instruction aligning with ambitious mathematics practices.

Developing Trust. Developing trust with teachers—a critical component of coaching relationships—was addressed in several articles (Hartman, 2013; Mudzimiri et al., 2013; Neuberger, 2012; and Zepeda & Kruskamp, 2007). Zepeda and Kruskamp (2007) found that a key to instructional supervision building trust. For example, one department chair stated that winning trust was important to set the tone for a caring relationship. They modified their supervision practices based on the teacher they were working with to support them as an individual. This was done through establishing a

personal relationship, so the teachers felt comfortable in listening to feedback. In addition, approaching instructional supervision from a formative rather than an evaluative position, giving teachers tools and support, listening, and developing good relationships were important so that supervision was non-threatening. However, because of time constraints, department chairs checked on teachers on an as-needed basis as it was not a priority of the administration. This hindered relationship development with teachers (Zepeda & Kruskamp, 2007).

Hartman (2013) discussed the importance of the mathematics coach developing trust with the teachers to enter classrooms. In order to begin to develop trust, she worked hard to maintain confidentiality and she maintained a delicate balance between peer and supervisor in her relationships with teachers. This helped her enter and support most of the teachers at the school (Hartman, 2013). Mudzimiri et al. (2014) echoed these themes when discussing the relational strategies used by coaches. The coaches paid particular attention to the bond they had with teachers through promoting trust, goal setting, and mentoring by engaging in personal conversations during coaching sessions in addition to providing instructional support. This approach was successful because while teachers saw the coaches as instructional experts, they did not feel like there was a component of supervision or evaluation in their coaching (Mudzimiri et al., 2014). Neuberger's (2012) study found that the relationship between an elementary teacher and a mathematics coach was critical to the development of the teacher's instructional strategies. The coach worked to develop rapport by taking cues from the teacher and by treating her as a professional and expert. The teacher was enthusiastic and unafraid to show her insecurities when working with the coach who showed confidence in the teacher

(Neuberger, 2012). Developing trust was a critical component of working with mathematics teachers and providing feedback by building rapport.

Feedback to Teachers. While co-teaching or observing teachers was a common activity found in the literature, it was also found that not much time was spent planning and debriefing the co-teaching experience (Chval et al., 2010). Three articles discussed giving feedback to mathematics teachers (Gibbons & Cobb, 2016; Mudzimiri et al., 2017; Neuberger, 2012). This is an important component of mathematics leaders' activities to improve instruction. Mudzimiri and colleagues (2017) claim that the key to facilitating teacher learning comes from a focus on planning, enacting, and improving lessons. This is accomplished through providing feedback through pre- and post-lesson conversations, reflective questioning, and debriefing. Debriefing after a lesson is an important way to develop an instructional focus for future coaching. When examining conversations between mathematics coaches and teachers, coaches were both collaborative and directive in their feedback to teachers. Collaboration was frequent but there were still times when the coach influenced the direction and the tone of the conversation or conference. A more directive conversation put the coach in a hierarchical or expert position which can be either positive or negative depending on the context of the conversation (Mudzimiri et al., 2017).

Gibbons and Cobb (2016) reached similar conclusions and stress that observing classroom instruction and debriefing is key to supporting teacher learning. Providing feedback, identifying areas to work with the teacher, and goal setting are important in developing ambitious mathematics practices. Specifically, a mathematics coach working with a new teacher who struggled with the pacing of lessons used their knowledge of how

new teachers learn to develop short-term goals for the teacher. One example was supporting the teacher to allow more students to answer questions to check student understanding. The coach also observed students' ability to work on the task and opportunities to share their work, and supported the teacher in developing discourse moves, clear expectations, and questioning (Gibbons & Cobb, 2016). These coaching practices supported the new teacher in developing ambitious mathematics practices.

Neuberger (2012) illustrated a post-observation conversation with a teacher that was linked completely to the lesson. This conversation was spent looking at students' work and thinking. The mathematics coach stressed the importance of reasoning and sense making for students and was able to model the reasoning process for the teacher when making instructional decisions. Additionally, the coach modeled the process of choosing a task that promoted thinking and reasoning for students (Neuberger, 2012). Goal setting, collaboration, and focusing on student thinking are critical to providing feedback to teachers. Overall, providing supports for teachers through co-teaching, modeling, and team meetings, developing trust with teachers to provide feedback, and giving effective feedback to teachers were all exemplary ways that mathematics leaders provided support for teachers. This has the potential to provide support for ambitious mathematics practices through sharing lesson ideas, modeling ambitious practices, and helping teachers set goals to improve their practice.

Teacher and Student Outcomes

Few studies have addressed the outcomes of coaching for mathematics teachers and students (Ellington et al., 2017; Hopkins et al., 2017; Neuberger, 2012). Ellington et al. (2017) found that having highly engaged teachers working with a mathematics coach

has the potential to change teacher effectiveness. Of the 201 teachers in their study, 40.5% were classified as highly engaged with the coach at their school; however, there was a high level of variability across the schools ranging from 6.7% to 70.6% of highly engaged teachers. Students of teachers who were not highly engaged scored lower on state standardized assessments overall than those of teachers who were highly engaged (Ellington et al., 2017). Neuberger (2012) found that when working with a mathematics coach, teacher beliefs changed. The teacher highlighted in the study became more comfortable relinquishing control of her lessons and focusing more on student contributions and discussions because of the coaching she received. The coaching influenced her beliefs which impacted her instructional practices. She started implementing practices where students collaborated in divergent thinking and were encouraged to make their thinking public (Neuberger, 2012). The four coaches in Hopkins et al.'s (2017) study facilitated connections between teachers to support engagement in changing mathematics instruction. Teachers had more opportunities to participate and take charge of these changes. The presence of a coach had impacts on instruction and student achievement in three studies. It is notable in Neuberger's study that the coach influenced the teacher to use instruction that was in alignment with ambitious mathematics practices.

Summary

A majority of the articles found addressed the relationship between mathematics teachers and mathematics coaches. In this section, it was important to discuss the role that mathematics coaches played within the school and examples of positive coaching practices. Major themes that emerged included developing trust, supporting teachers

through modeling, co-teaching, facilitating team meetings, and providing feedback. In contrast to the relationship between mathematics teachers and administrators, there were more examples of support from mathematics coaches. One area that was not addressed in depth within the literature was outcomes for teachers and students with the support of a mathematics coach. This is one potential area for research. There were articles that illustrated how the duties of coaches can take away time from coaching activities. In the next section, I discuss other conflicts of the coaching role as I explore the relationship between coaches and administrators.

Administrator/Mathematics Leader Relationships

While mathematics coaches can enhance instructional practices and provide critical instructional support to mathematics teachers, conflict within their role can also exist. In particular, two areas of conflict were seen in the literature: the ambiguity of the job description and school administrators' influence on the position. These are both external influences on the mathematics leadership role.

Ambiguity of Leadership Role

I found that the ambiguity of the leadership role for mathematics coaches was one theme in the literature and was a source of stress for many within a mathematics leadership position (Chval et al., 2010; Hartman, 2013; Knapp, 2017; Zepeda & Kruskamp, 2007). For example, in an autoethnography of an emerging teacher leader, Knapp (2017) expressed confusion about leadership and lacked confidence and certainty about her capabilities as she did not have a defined role from her administration or the formal title of a leader. Many of her colleagues questioned why she was taking on additional responsibilities with the administration. The most problematic aspect of her

role was when the principal shared negative information about other staff members. Knowing this information made her feel uncomfortable as she found it difficult to navigate the space between colleagues and administration and did not feel connected to either group as an informal leader. Furthermore, Knapp felt a lack of communication from administration about the implementation of the ambitious mathematics instructional practices and did not feel that her principal knew how to support her. She questioned whether her principal believed in a distributed leadership model (Knapp, 2017). Chval et al. (2010) identified similar issues of mathematics coaches feeling caught in the middle between teachers and administrators and noted that these leaders expressed conflict in feeling like a spy.

Chval et al. (2010) also found discrepancies within the enacted roles of leadership; the expectations and job description of the coaching role conflicted with how the role was enacted when coaches worked with teachers. For example, coaches were not always welcome in classrooms and were surprised by the teachers' resistance for support. Hartman (2013) described a similar experience in which a rural Appalachian school mathematics coach who found it difficult transitioning into a leadership role. Success as a classroom teacher didn't translate into being accepted in her new role by the other teachers and she felt it necessary to justify both her salary and contribution to the school. The coach was first seen as an outsider and had to earn teachers' trust to visit classrooms. She had particular difficulty with two experienced seventh grade math teachers who did not want to meet with her and were resistant to changing their teaching methods to more ambitious instructional practices. This limited her ability to support with developing a conceptual focus for mathematics teaching in classrooms (Hartman, 2013).

In another example (Zepeda & Kruskamp, 2007), department chairs were never given a formal job description nor any professional development to support their role, even though they did have a more formal leadership title. These department chairs felt that coaching (referred to as instructional supervision in this article) was an important role for them; however, it was not a role administrators directed them to provide. The task of instructional supervision was modeled by former department chairs, so current chairs used this along with their own views of what they believed to be best to enact their roles. This led to a source of conflict within the role because there wasn't enough time to perform all of the tasks that were required for the job and little time was allotted for instructional supervision. The expansion of high stakes testing limited the coaching role more to working with groups of teachers rather than with teachers individually (Zepeda & Kruskamp, 2007). In this section, confusion, conflicting responsibilities, and a lack of formal job description were all important factors that contributed to the effectiveness or ineffectiveness of the mathematics leadership position.

Influence of Administrators on Mathematics Leader Roles

When school leadership follows a distributed model, with multiple levels of support for teachers, administration still plays a critical role in influencing the enactment of mathematics coaching for teachers as discussed in three articles (Hopkins et al., 2017; Knapp, 2017; Mangin, 2007). Knapp (2017) found that a lack of communication with administration impacted the relationship with the mathematics department. The mathematics team had to work to convince the administration about the legitimacy of the instructional strategies that were being used in their classrooms and felt that administration didn't understand their teaching practices. The principal often missed

meetings which made teachers frustrated and resistant to communicate with members of administration.

Mangin (2007) examined five school districts' models of teacher leadership that included full-time instructional coaches. The instructional coaches were supervised by the districts' central administration and their role included lesson modeling, providing resources for teachers, and building professional development opportunities. However, across the districts, there was a high level of variability in the types of interactions between the instructional coaches and school level administration. For example, in one district that held regular meetings between instructional coaches and principals, the coaches facilitated a better and more accurate implementation of the coaches' role. In another district, principals were given more authority in deciding tasks for the coaches, but this led to inconsistent implementation of coaching between the schools. This led to variability in effectiveness of enacting their role of teacher leader within the school. Principals in these five districts varied in their knowledge about the instructional coach role, their interactions with, and support for the leader affected the quality of coaching. Those principals with less knowledge of the role tasked the instructional leaders with non-coaching related duties like facilitating testing, clerical duties, and ordering school supplies. The principals with more knowledge of the role were more supportive of and held higher expectations for coaches to work with teachers, even requiring teachers to work with the coaches. For teacher leaders who had less support from principals, this limited their ability to be effective in their role (Mangin, 2007).

Hopkins et al. (2017) echoed these themes as both the district and school administrators played critical roles in the effectiveness of mathematics coaches. The

district provided extensive knowledge, professional development, and support for the new curriculum that coaches could take back to their schools. In addition, the process of collaboration and inquiry modeled by the district mirrored the support provided to teachers. Emphasis was placed on administrators' support for mathematics coaches in developing relationships with the teachers. Principals played a critical role in helping coaches navigate interactions with teachers and the political tensions that could arise. Leadership plays an important role in setting norms of collaboration within the school to support the work of mathematics coaches. A coherent strategy between school leadership and mathematics coaches is more likely to create and support system-wide instructional change in mathematics (Hopkins et al., 2017). Furthermore, a lack of communication between the two role groups can hinder the support for mathematics teachers.

Summary

This theme highlighted how distributed coaching models can look different from school to school due to a lack of definition in the mathematics leadership role and the relationships with administrators. However, few studies explored this relationship. Some mathematics leaders did not have a formal title or the time to spend with teachers in a coaching capacity (Knapp, 2017; Zepeda & Kruskamp, 2007). Coaches found it difficult to take on the leadership within a new role from navigating the relationships between administrators and teachers or feeling unwelcome in working with teachers (Chval et al., 2010; Hartman, 2013). Administrators can support these roles with consistent communication; however, this was not always the case. Although a consistent definition of the coaching role was not evident in the literature, it is important to focus on the actions of school leaders and that much can be accomplished through collaboration

(Knapp, 2017). A lack of collaboration or an ambiguous role can hinder the support for developing ambitious mathematics practices as it takes time and opportunities away from working directly with teachers.

Conclusions

The prior synthesis papers I reviewed called for more research on administrators' relationships with mathematics leaders and mathematics leaders work with teachers to improve instruction. I sought to examine these relationships more in depth. Specifically, my literature review looked at the relationships between administrators, mathematics leaders, and mathematics teachers within K-12 schools. Three relationships emerged: the relationship between administrators and mathematics teachers, the relationship between mathematics coaches and teachers, and the relationship between administrators and mathematics coaches. From these relationships, the literature revealed both internal and external factors that influence the content-specific coaching given to mathematics teachers. Internal factors included background, beliefs, and prior experiences. External factors included learning opportunities and interactions with mathematics teachers. A majority of the literature discussed administrators' lack of content-specific feedback given to mathematics teachers. Mathematics leaders are able to provide better feedback to mathematics teachers; although external factors included the requirements to play many different roles in the school. These roles were often unrelated to supporting mathematics teachers. Finally, the literature highlighted that administrators could affect the mathematics leader role through a clear definition of responsibilities and effective communication (also external factors).

Areas of Future Research

These relationships highlighted three gaps within the literature. First, very few articles discussed teacher or student outcomes. This would be an important topic to further explore. Specifically, it is important to explore the outcomes of content-specific coaching related to the development of ambitious mathematics practices along with students' conceptual understanding. Second, there was a variability in the samples explored for this research. Many of the articles had large sample sizes in looking at many schools and often several districts. In contrast, there were articles that looked at one mathematics coach and the teachers they worked with. None of the articles looked at the totality of the leadership and mathematics teachers at one single school. Also, only two articles explored the high school setting. Finally, while some articles addressed both relationships between teachers and mathematics leaders and mathematics leaders and administrators, none of the articles explored the relationships between mathematics teachers, mathematics leaders, and administrators. The problem here is that we can't know the complete impact of supporting mathematics instruction because these studies only consider one or two relationships. Cobb and colleagues (2003) claim that teaching is distributed across several communities of practice including various levels of leadership. Instructional practices are intertwined within the activities of different members (Cobb et al., 2003). This is important because the support that teachers receive and the types of instructional practices that are enacted can be influenced by various roles and the relationships that develop between them (e.g. the relationships between mathematics leaders and administrators). Further exploring the links between administrators, mathematics leaders, and mathematics teachers provide insight into supporting mathematics instruction in schools.

CHAPTER 3: METHODS

To address the gap in understanding how administrators, mathematics leaders, and mathematics teachers strive to achieve the outcome of ambitious mathematics practices while facing pressures of test scores and graduation competencies, I conducted a qualitative, descriptive, single case study in a high school setting. The purpose of the study was to describe the work of school leaders—both school administrators and mathematics leaders—with mathematics teachers at a large, suburban public high school. This study addressed the primary research question: How do the relationships between administrators, mathematics leaders, and mathematics teachers at a large, suburban public high school support ambitious mathematics practices? Sub-questions include:

- How do internal and external factors influence administrators and mathematics leaders' support of ambitious mathematics practices with mathematics teachers?
- How do administrators and mathematics leaders provide content-specific coaching to mathematics teachers to support ambitious mathematics practices?
- How do administrators collaborate with mathematics leaders to support ambitious mathematics practices?
- How do mathematics teachers perceive administrators' and mathematics leaders' support of ambitious mathematics practices?

To address these research questions, I took a feminist approach to the research and used an instrumental case study design (Creswell, 2013; Stake, 2003) in which I collected data through interviews, observations, and artifacts from mathematics teachers, mathematics leaders, and school administrators. Sociocultural theory and concepts of ambitious mathematics practices, as well as emerging themes, informed my analysis. My findings provide insights into components for school administrators, mathematics leaders, and mathematics teachers to support ambitious mathematics practices (Silver & Herbst, 2007).

Epistemology and the Qualitative Approach

The epistemological approach underlying this research is pragmatic realism (Cobb, 2007) which questions the traditional epistemological approaches of positivism and radical constructivism by challenging the idea of Reality (with a capital “R”). This Reality is imaginary and separated from a world where people participate in daily life (Cobb, 2007). In his discussion of pragmatic realism, Putnam (1987) takes the realities at face value and the theoretical perspectives that researchers use; however, he makes the argument that these should be used to examine practice instead of making claims about Reality (with a capital “R”). Putnam states, “But mundane reality looks different, in that we are forced to acknowledge that many of our familiar descriptions reflect our interests and choices” (p. 37). Therefore, the purpose of using a qualitative research approach is to examine the practices of school leaders and mathematics teachers within reality (with a lowercase “r”) while paying particular attention to reflexivity and the interests I am bringing to the research (Cobb, 2007).

In addition, I took a feminist approach to this research project by paying particular attention to my bias and reflexivity, validity, voice, and ethics (Olesen, 2018). While this research project does not necessarily address issues of feminism directly, the goals of this approach fit the aims of my study. DeVault and Gross (2006) state that the origins of feminist research are concerned with relationships between researcher and participants and the implications of generalizing on the basis of science. Because I addressed the tension between theory and practice within mathematics education as outlined by Silver and Herbst (2007), and the disconnect in applying theory into practice with ambitious mathematics practices, this was an appropriate approach. In addition, feminist research takes an activist approach where the goal is to change structures and bring activist ideas to a broad audience. The goals of my research were to study the activist ideas of ambitious mathematics teaching to create equitable opportunities for student learning. Feminist research tackles the issue of knowledge, for whom it benefits, and the purposes that it serves (DeVault, 2018). Because of this, it was important to pay particular attention to the benefits of my research for the participants in the study. Lincoln (1995) concurs and states that qualitative research should serve those in the community where the research is conducted, and that research should be first a community activity as it is impossible to study people without also studying the relationships between them (Lincoln, 1995). Along with the ideas of ambitious teaching, it was important that this research benefits administrators and mathematics teachers to create equitable opportunities for students.

Finally, I approached this research from a teacher solidarity lens (Phillip et al., 2016). Using this approach, I am acknowledging my position as a current teacher who is

also a novice in navigating the research process which creates a unique tension between the two spaces. Through this lens, I am acknowledging how difficult the career of teaching is and the frustrations that arise, and also the difficult situations that school leaders face as they navigate the pressures created by the reform climate of education with their own visions and goals. Common challenges for teachers and school leaders include the erosion of teaching as an intellectual and creative endeavor and the limitations that educational policies can place on both teachers and school leaders, the difficulty of learning how to teach and also learning how to lead teachers, acknowledging that we are not perfect teachers or perfect leaders, the feelings of isolation experienced by teachers and school leaders, and the disregard for practice-based knowledge in research (Phillip et al., 2016). Through this lens, I attempted to acknowledge all participants' voices in my research and ensure that these voices and opinions were shared equally. I acknowledge that identities continuously change social, political, and institutional contexts.

Case Study

The epistemological question that a case study asks is what can be learned from studying the particular (Stake, 2003). Studying the particular contrasts with studying for generalizability by focusing on the unique aspects of the single case. For my study, the nature of the case, the setting, and the participants through which the case can be known were all important factors. What separates case study as a methodology from just a method is the attention to its epistemology and the historic tradition (Hyett et al., 2014). Yin (2018) argues that case study is best used when asking *how* or *why* questions, when the researcher has no control over the behavior of participants, and when it focuses on

contemporary issues. In addition, a case study requires a theoretical framework that guides the design, data collection, and analysis and triangulates the findings through multiple sources of data (Hyett et al., 2014; Yin, 2018). Adherence to the methodological design is imperative for the methodology of a case study (Farquhar, 2012) which is described in depth later in this chapter.

Farquhar (2012) defines case study research as that of “studying a phenomenon in context so that the findings generate insight into how the phenomenon occurs in a given situation” (p. 6). The goal of a case study is to gain a deep understanding. The advantage of the case study approach is the collaboration between researcher and participant which supports participants in telling their stories (Baxter & Jack, 2008) and allows the researcher to connect participant actions with reality. While illuminating reality, it is important to define the boundaries of the case study and one way to do this is through definition and context (Baxter & Jack, 2008). In this study, the definition of the case is a high school mathematics department supporting ambitious mathematics practices and the context is the interactions between school leaders and mathematics teachers to implement these practices. This research meets the criteria for three types of case studies: single case study, instrumental case study, and descriptive case study.

Single Case Study

I chose one case for this study to provide an in-depth picture rather than multiple cases or schools. A case comparison detracts from learning about the particular case and examining the differences between multiple cases is less trustworthy than the conclusions of the single case. This is the opposite of providing thick description (Stake, 2003). Studying the particular school and mathematics department provided a strong description

of leader practices and interactions with mathematics teachers and contributes to the body of research.

Instrumental Case Study

The goals of an instrumental case study are to understand a particular situation (Stake, 2003). The case selected was instrumental to the study as there are few schools in which implementation of ambitious mathematics practices was a department or school-wide goal. The goal was to better understand the practices of school leaders in supporting mathematics teachers to create these changes to instruction. Studying an instrumental case involved examining the activities and the context of the case in depth to facilitate the understanding of the change (Stake, 2003).

Descriptive Case Study

Yin (2003) defines a descriptive case study's goal as describing the context in which a phenomenon has occurred. This differs from an exploratory or explanatory case study where the goal is to identify questions for future research or to explain how a situation came to be. This case described the mathematics department at the high school and focused on the school leaders' practices and interactions with mathematics teachers within this context.

Researcher Positionality

It is important for the qualitative researcher to state their positionality as a way to make explicit their personal biases that relate to the research topic. I am a white, middle-class female. I have been a secondary mathematics teacher for ten years and have taught at five different schools in the metropolitan area where I conducted my research. I have worked in public schools, private schools, high-income suburban schools, and diverse

low-socioeconomic schools. I had not worked in the school that is the focus of this research nor with any of the teachers or administration prior to conducting this study. However, after developing a relationship with the mathematics leaders and a few of the administrators at the school, they became excited about the possibility of me teaching at the school as well. Therefore, it was my first year teaching mathematics at this school while I conducted my research. This created both opportunities and challenges in my research. This school is located in the same district in which I grew up and taught in for part of my career; therefore, I have been a member of this district and neighboring community for many years.

Beginning in 2006, my teacher education has afforded me unique experiences that contributed to my philosophy of teaching and as a result I have embraced ambitious mathematics practices as a classroom teacher. In trying to implement these practices, I have often been challenged from many angles, particularly from administrators who oversaw my formal evaluations. Several administrators were not familiar with these ambitious mathematics practices or with mathematics content in general and as a result, were hesitant to change from traditional patterns of mathematics. Collaboration between students and inquiry approaches have often been mistaken for weak classroom management and results in recommendations for more structure (i.e., desks in rows, structured lectures, practice, and an “I do, we do, you do” instructional design). School leaders have questioned my practices, given me lower evaluation scores, and even non-renewed me for a teaching position. These experiences have made me even more committed to exploring and closing the gap between research and practice in mathematics

education instruction to support both teachers and students in implementing these practices.

I was fortunate to teach at a school that aligned with my beliefs as a teacher and as a researcher. I immediately felt at home and understood and formed quick relationships with others in the mathematics department. Everyone was supportive and willing to participate in the research. I was grateful to be able to continue to work as a full-time teacher while completing my dissertation. Balancing time was hard. I was learning a new curriculum and lesson planning took a lot of time. I had more papers to grade, and I wanted my colleagues and supervisors to see my strong work ethic. I did not want to give anybody the idea that I was just there to do my research.

I knew that balancing the roles of a teacher and a researcher was going to be difficult. There were times where the lines were blurred between information I gathered as a co-worker and information I gathered as a researcher. Sometimes I second-guessed myself after sharing something with a colleague and wondered whether I should have shared it and where was the source of the information. When co-workers disclosed their frustrations in interviews, I wanted to share my frustrations as a teacher too. I was having my own experiences as a teacher but also hearing similar experiences during my research. Talk around “the water cooler”, in teacher offices, or at staff happy hours were the hardest to navigate for me as a teacher versus a researcher. I strived to document each instance when the lines became blurred through memos throughout the year.

Setting

The school setting for this study was a purposefully selected because of its continued use of ambitious mathematics practices (Creswell, 2013). A high school was an

ideal site for two reasons: first, high schools are underrepresented within the literature on this topic (Lochmiller, 2016; Zepeda & Kruskamp, 2007); second, as a middle school mathematics teacher for my entire career, a high school provided me with an opportunity to approach a different educational setting. The school is located in a large suburban school district containing many large traditional high schools and a few smaller charter options. The focal high school has been open for twelve years with over 2,000 students served by more than 120 teachers. The student population includes a majority of white students and a low percentage of the students are economically disadvantaged. On the PSAT/SAT, students perform higher than the state level with average scores around 500 for Evidence-Based Reading and Writing and around 480 on Math (State Department of Education Website, 2019). However, SAT scores were the lowest of the nine traditional high schools in the district.

The school's mission highlights strong relationships, relevant learning, and a rigorous academic environment to support students in developing 21st century skills (School Website, 2018). It provides students opportunities to pursue particular academic interests including health and science, STEM, leadership and communications, and arts through an academy model with teachers working in interdisciplinary teams in one of the four academies. Many students culminate their high school experience with internships or certification programs in identified areas of interest (School Website, 2018). The school operates on a block schedule where students take four year-long courses in one semester (4x4 block). This allows them to take more mathematics credits than the traditional four year-long credits at other high schools. All students can reach college level mathematics during high school regardless of their starting level of mathematics. Some students take

many more mathematics credits than the required three; others take the minimum requirements.

Students are placed into their mathematics class based on their previous experiences and classes taken in high school. The school is considered de-tracked because students are placed into mixed grade-level classes and there is no honors or regular track. It offers five levels of integrated mathematics where students learn Algebra, Geometry, Trigonometry, introductory Calculus concepts, and probability and statistics. They investigate common math concepts such as multiple representations, rate of change, similarity, data collection and analysis, and use of models. Students are also expected to use the following habits of a math learner on a daily basis: grit, curiosity, awareness, risk taking and social learning (School Website, 2018). After completing math levels one through five, students have the opportunity to take Advanced Placement Calculus, Statistics, or a Community College dual enrollment courses because of the opportunity to accelerate and the common curriculum used. The school uses the *Interactive Mathematics Program* (IMP; Fendel et al., 1999) to provide students with rigorous and relevant experiences that promote problem solving and learning (School Website, 2018). IMP has shown to have positive effects on student achievement, including completing more mathematics courses, better performance on the NAEP, better performance on application problems, and higher SAT scores—especially when coupled with a 4x4 block schedule (Huntley & Terrell, 2014; Kramer & Keller, 2008; Webb, 2003). However, it also has garnered criticism as failing to meet the needs of students who intend to pursue college subjects related to mathematics, lacking a depth and breadth of topics and insufficient coverage of the technical components of mathematics (Wu, 2000).

Participants

The principal, two administrators who work closely with the mathematics department, the mathematics coach, the mathematics department chair, and five teachers—recommended by the mathematics coach and department chair in order to gain diverse perspectives—participated in the study. All names in this study are pseudonyms and I rounded their years of experience as a measure of confidentiality.

Table 3.1

Participants

<u>Participant</u>	<u>Role</u>	<u>Mathematics Teaching Experience (years)</u>	<u>Leadership Experience (years)</u>	<u>Group</u>
Alex	Principal	None	5 to 15	Out-Group
Jamie	Administrator	None	5 to 15	Out-Group
Andy	Administrator	None	5 to 15	Out-Group
Cam	Math Coach	Less than 5	More than 15	In-Group
Jesse	Department Chair	More than 15	5 to 15	In-Group
Shay	Teacher	Less than 5	None	In-Group*
Taylor	Teacher	Less than 5	None	Out-Group
Blair	Teacher	More than 15	5 to 15	In-Group
Riley	Teacher	Less than 5	None	Out-Group
Jordan	Teacher	More than 15	5 to 15	Out-Group

Note. While Shay was mostly aligned with the In-Group, they moved between the two.

Data Collection

Yin (2018) outlines six sources of evidence in case study research and I used five of these to answer my research questions: interviews, observations, participant-

observations, documentation, and relevant artifacts. Creswell (2013) states that it is important to draw on a variety of information in a case study design to provide an in-depth picture; thus, the description of a single case through different sources of data provided a thick description of the case (Stake, 2003). Data were collected over the period of one school year. Table 3.2 illustrates how my data collection aligned with my research questions/case study propositions and the literature.

Table 3.2

Research Propositions, Data Source, and Analysis

<u>Proposition/Literature Findings</u>	<u>Key Citations</u>	<u>Data Collection</u>
Primary Research Question: Interactions with mathematics leaders are more content specific than interactions with administrators.	Ellington et al. (2017) Gibbons & Cobb (2016) Mette et al. (2015) Nelson (2010) Neuberger (2012)	Teacher interviews Leader interviews Observations Participant Observations Documentation/Artifacts
Sub-Question 1: Work with mathematics teachers is influenced by both internal and external factors.	Burch & Spillane (2003) Lochmiller (2016) Nelson (2010) Rigby et al. (2017)	Leader interviews Observations
Sub-Question 2: Leaders support mathematics teachers by providing feedback, modeling/co-teaching, and developing trust.	Ellington et al. (2017) Gibbons & Cobb (2016) Neuberger (2012) Zepeda & Kruskamp (2007)	Teacher interviews Leader interviews Observations Participant Observations Documentation/Artifacts
Sub-Question 3: Collaboration between administrators and mathematics leaders is inconsistent.	Hopkins et al. (2017) Mette et al. (2017) Mangin (2007)	Leader interviews Observations Participant Observations

Sub-Question 4: General feedback does not support the development of ambitious mathematics practices; coaches were able to provide content specific feedback.	Burch & Spillane (2003) Lochmiller (2016) Mette et al. (2015) Rigby et al. (2017)	Teacher interviews Observations
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Interviews

Interviews are crucial for case study research (Yin, 2018) because they provide insights into participants' perceptions by answering the "how" and "why" questions. Case study interviews follow the structure of a guided conversation rather than a formal interview (Yin, 2018). Data obtained through interviews may not constitute authentic data or data that is an exact representation of the participant's reality; however, interviews are a co-construction of the data through conversation (Roulston et al., 2003). I adopted a feminist interviewing approach to collaboratively make meaning with the participants (DeVault & Gross, 2006). In order to engage in this process, I was an active listener and attuned to pauses, difficulties in communicating ideas, and gaps. In addition, a co-construction of meaning-making involves strategic disclosure of personal information or discussing research interests during the interview (DeVault & Gross, 2006). During interviews, I shared my personal experiences and discussed the research process with participants in order to build relationships. Through these interviews I gained insight into the relationships between administrators, mathematics leaders, and mathematics teachers in supporting ambitious mathematics practices. Individual semi-structured interviews with each school leader and mathematics teacher participant occurred twice during the year.

In accordance with Creswell's (2013) recommendation for good interviewing procedures, I completed a pilot interview prior to formal data collection to ensure that questions were worded correctly and captured the proper data to answer my research questions. The first interview protocol drew from Lochmiller's (2016) study exploring administrators' leadership in mathematics and science in high schools (see Appendix B) and focused on participants' background, beliefs about mathematics learning, and experiences in working with leaders or teachers. The second interview was adapted from Munter's (2014) Vision of High-Quality Mathematics Instruction (VHQMI) interview protocol and Jackson and colleagues' (2017) Views of Students' Mathematical Capabilities (VSMC) interview protocol. The purpose of the VHQMI was to measure the trajectory of progress toward ambitious mathematics practices and individual understanding of these practices (Munter, 2014). Its use was for an agenda of problem solving, conceptual understanding, sense making, students driving their own learning, and communication. The VSMC was important for the development of ambitious mathematics practices because if teachers do not hold productive beliefs about their students, they are unlikely to provide ambitious opportunities for them (Wilhelm et al., 2017). It was important to include these measures for evaluating instructional improvement efforts (Jackson et al., 2017).

I scheduled the first interview with participants in late fall of the school year. Transcriptions were completed between each interview to the best of my ability. The second interview was scheduled toward the end of the school year, in April. I also asked participants for suggestions of additional interviewees or observations that might be valuable as suggested by Yin (2018) to ensure I was not missing important data. No

additional interviews or observations were suggested. In all, I completed nearly 40 interviews and observations throughout the year. I ensured that I correctly captured participants' ideas through member checking of transcripts.

Observations

Observations operate along a continuum from formal or informal in nature (Yin, 2018). I conducted observations during coaching sessions, evaluation meetings, and within classrooms. In accordance with my feminist research approach, I took the roles of both a nonparticipant-observer and a participant-observer (Yin, 2018). Non-participant observations were most appropriate during coaching conversations or post-observation conferences. For coaching sessions and evaluation meetings, I used NCTM's *Principles to Actions* (Leinwand et al., 2014) along with the Visions of High-Quality Mathematics Instruction (Munter, 2014) and Views of Students Mathematical Capabilities (Jackson et al., 2017) rubrics. In addition, to gauge the depth of groupwork conversations I used A Taxonomy of Learning in Groupwork Conversations (Horn et al., 2017) and the Seven Stages of Professional Learning Teams (Graham & Ferriter, 2008). Both frameworks categorize conversations along a trajectory showing the productiveness of conversations and classifies the focus of student learning. The goal of each observation was to capture the process of supporting ambitious mathematics practices. I wrote both descriptive and reflective observation notes, including reflexive notes (Creswell, 2013). These notes included participant descriptions, and my reactions to what I observed, ideas and initial interpretations. In addition to notes, my observations were audio recorded for transcription.

In addition to observations, participant-observations were also used. The role of the participant-observer included participating in the environment being studied (Yin, 2018). Participant-observations occurred throughout the school year and I took notes or reflected on instances of participation that I felt were significant. Following Creswell's (2013) classification, I moved between the participant as observer role and the observer as participant. Participation include offering ideas or suggestions, participating in various activities, or supporting students in classrooms. Participant observation provided access to certain activities as well as the viewpoint from an insider perspective (Yin, 2018). Because biases resulted from taking a participant-observer stance, I was reflexive throughout this process.

Documentation and Relevant Artifacts

I collected any relevant artifacts including written teacher feedback and evaluation data, and my email correspondence with participants, meeting notes, and artifacts from classroom observations (Yin, 2018). These sources supported the verification of both interview and observational data in understanding how school leaders at the high school work with mathematics teachers to support ambitious mathematics practices. When relevant, documents and other artifacts were an important source of data; however as Yin (2018) notes, they should be used cautiously as they aren't always without bias and should not be taken at face value. Only a few documents and artifacts proved to be useful.

Data Analysis

Yin (2018) states that analysis of case study data rarely follows a regimented structure and can vary depending on the preference of the researcher. He suggests first to

play with the data which includes visual displays, matrices, counting frequencies, or sequencing the data. After data collection, I completed all the transcriptions and organized files for my data categorized by role, participant, and date. I reviewed all observation notes, interview transcripts, and artifacts, and made notes and memos. It was helpful to complete these in between data collection sessions in order remember details from each of the instances (Yin, 2018). However, this was not always possible with the amount of data collection and balancing my responsibilities as a teacher. DeVault and Gross (2006) state that part of feminist research is being mindful of narratives and their link to identity and participants' sense of the world. It was important to pay attention to what is referred to as institutional ethnography, or how personal experience is linked to the rule or institutional authority structure (DeVault & Gross, 2006). I incorporated these ideas and followed Saldaña's (2016) methods of first and second cycle data coding.

The first level of coding consisted of an eclectic coding strategy (Saldaña, 2016). Eclectic coding utilizes multiple forms of coding to gain insight into the data. I utilized three coding strategies. First, holistic coding provided me with a sense of emerging themes as I explored the data as a whole when listening to interviews and reading over notes. Second, in vivo coding helped me categorize different pieces of data that made it easy to manipulate. Third, structural coding linked data specifically to the research questions and theoretical and conceptual frameworks of sociocultural theory and ambitious mathematics practices. I started data analysis by identifying significant quotes from the data collected. I used a two-column notetaking system to write reflections, words, and statements using the three types of coding I identified.

Second cycle coding supported another level of analysis and organization of the data and themes first collected. The second cycle coding method I used was pattern coding, where categories are grouped into a smaller number in order to produce themes (Saldaña, 2016). Creswell (2013) refers to this as establishing patterns where the researcher looks for conversations between multiple categories of data and suggests that tables be used to show the relationships between categories. Creswell also advocates for naturalistic generalization and description of the case to gain an in-depth idea of the case as well as making explicit what can be learned from examining the case.

Second cycle coding took a variety of forms. I would often start by making a list of first cycle codes that fit within a similar theme. I would then organize these lists into tables or concept maps to help organize the data and look for patterns. Sometimes the patterns were based on the relationships, others were based on research questions, and a lot of times, patterns emerged from seeing trends in the data itself. I would then write a description or reflection of what I found. After second-cycle coding, I would go back to my original raw data to ensure that the patterns I found captured the essence of the data from interviews and observations and identify the most powerful or iconic quotes to include in the findings. To summarize, after gathering data, transcribing interviews, and making detailed notes about the data collected, I followed Saldaña's (2016) suggestions for first and second cycle coding. Second cycle coding led into Creswell's suggestions for naturalistic generalization and thick description of the case.

Trustworthiness

Schoenfeld (2007) outlines six criteria for trustworthiness in mathematics education research including, descriptive and explanatory power, prediction and

falsification, rigor and specificity, replicability, triangulation, and generality and importance. I elaborate on four of these areas as they relate to the trustworthiness of my qualitative case study.

Descriptive and Explanatory Power

Descriptive power is the ability for the theory to describe the case while explanatory power is the explanation of how and why a phenomenon functions in a particular way and asks if the claims are held accountable to the data (Schoenfeld, 2007). Theory is embedded throughout my study design, from the themes in my literature review through the empirical base, use of case study, and data analysis. Providing thick description and explanations of the phenomena of relationships at the research site provided descriptive and explanatory power. In addition, Tracy (2010) outlines two quality criteria that are important considerations: resonance and significant contributions. Resonance means that the findings are presented in an “aesthetic way” and provide readers with a “vicarious experience” (p. 845). Creswell’s (2013) notion of naturalistic generalization provide me with an avenue for these qualities. Significant contributions mean that others are motivated to act on the findings. Descriptive and explanatory power was achieved through the presence of theory, the use of thick description, and naturalistic generalizations.

Rigor

Rigor is the attention to the process of moving from a real-world situation to a conceptual or theoretical model to a representational situation (Schoenfeld, 2007). Several authors discuss the idea of rigor in qualitative research and outline a clear process for analysis (Anfara et al., 2002; Tracy, 2010). Tracy states that for a study to be

rigorous, it is necessary to ensure that there is both plenty of data and sufficient time to gather interesting data. Working as a teacher at the school allowed me to collect a large amount of data. In-depth data collection also ensured that interesting data is collected. Tracy, like Schoenfeld emphasizes the importance of the use of theory in the analysis process. I made my data analysis process explicit by outlining my coding systems and development of themes (Anfara et al., 2002). Rigor was achieved through sufficient data collection and an explicit data analysis process presented in the findings.

Triangulation

Triangulation of data was accomplished by collecting four types of data, member checking, and being mindful about participant voice. Because context can change how people act or what people say in certain situations, it was important to collect multiple sources of data to understand the same phenomena (Schoenfeld, 2007). In particular, documentation helped to verify data from observations and interviews to create better inferences (Yin, 2018). This adds credibility and adds to the idea triangulation in discussing multivocality (Tracy, 2010). Multivocality was paying particular attention to the variations in voices of participants, achieved through collaboration. Member checks were an important component in ensuring emotions and relationships between participants were properly conveyed (Tracy, 2010). Full member checks were completed by having participants read the presentation of results to ensure that I accurately portrayed their thoughts, emotions, opinions, and reactions. An important component of feminist research is to collect many forms of data and to be mindful of the voices of participants and the power relationships within research (DeVault & Gross, 2006). To maintain a teacher solidarity lens (Phillip et al., 2016), I revisited the data and checked

my themes against new and existing data to ensure that voices of all participants were shared equally and fairly. I was systematic about maintaining a teacher solidarity lens; as an example, completing full member checks.

Bias and Reflexivity

Reflexivity “demands steady, uncomfortable assessment about the interpersonal knowledge-producing dynamics of qualitative research” (Olesen, 2018, p. 160), in particular acute awareness to unrecognized elements of the researcher’s background. Earlier, I made my positionality explicit (Lincoln, 1995). Reflexivity also included keeping a research journal where I reflected on my location and power situated within my study and examined my own ideas throughout the research (Davies & Dodd, 2002). The idea of “critical subjectivity” (Lincoln, 1995) was also a source of journal reflection where I paid particular attention to emotions and personal reflections during the research process. These reflections were made explicit in the findings of the study through vignettes to ensure that bias was minimized through reflexivity and critical subjectivity during data collection and analysis.

Strengths and Limitations

A case study was an appropriate approach to answer my research questions about the relationships between school leaders and mathematics teachers and the support of ambitious mathematics practices in high schools because it was important to understand more about how these actors worked to support instructional change. Within the bounded system of a specific issue, it was important to use multiple sources of data (Creswell, 2012) to create a description of how the relationships between administrators, mathematics leaders, and mathematics teachers supported the use of ambitious

mathematics practices. Case studies allow for a large amount of data to be collected and provide a vivid and in-depth illustration of a unique situation (Terrell, 2016). This case study's strengths included its focus on the particular which allowed for an in-depth description of the phenomena (Stake, 2003). Furthermore, the feminist approach allowed for trustworthiness to be obtained through descriptive and explanatory power, reflexivity, rigor, and triangulation.

Common limitations of case studies include a lack of generalizability (Creswell, 2013). While not necessarily a goal of this research or case studies in general, transferability (the qualitative equivalent of generalizability) can be enhanced through thick description and use of theory (Creswell, 2013). Because this case study examined participants in one school, a more appropriate goal was to motivate readers and/or participants to reflect on and act on the findings of the study (Tracy, 2010). Vignettes and thick descriptions were used in the findings to ensure that the research process was both consistent and dependable (Terrell, 2016). In addition, theory was an important way to bridge the gap between research and practice (Silver & Herbst, 2007). Descriptive power used theory as a tool to provide a description of the case (Schoenfeld, 2007).

Researcher bias can influence the types of themes that are found within the data based on background and beliefs (Terrell, 2016). This can especially be a concern for more traditional researchers using a feminist or co-constructed research design. To address this potential limitation, I utilized triangulation of multiple sources of data and engaged in the research for a significant amount of time to build trust and understanding (Schoenfeld, 2007; Tracy, 2010). Furthermore, being reflexive and providing explicit description of the data analysis process helped to minimize bias. In addition, member

checks ensured that the participants' voices were accurately depicted. In conclusion, the case study design allowed for an in-depth description of the phenomena of the relationships between school leaders and mathematics teachers in supporting ambitious mathematics practices. Generalizability and bias were potential limitations but were minimized through description, use of theory, reflexivity, and explicit data analysis.

Ethical Considerations

While the first step in conducting an ethical study was to obtain approval from the university's Institutional Review Board along with approval from the school site and district, ethical issues also extended beyond the IRB approval process throughout the data collection, data analysis, and presentation of findings process. I began obtaining consent from the site of research, including the school district and school. I obtained consent forms for each person interviewed, observed, or stated in any document obtained during the data collection. All participants were assigned a pseudonym and data were protected on a secure computer drive. Ethics has to be a flexible process that is constantly evolving and changing (Davies & Dodd, 2002). Consent can be something that changes from day to day and lead to poor data (Tracy, 2010); therefore, it was necessary to ensure that trust was continuously developed. This was particularly important in navigating new collegial relationship while also being a researcher. To ensure that I was maintaining trusting relationships, I was explicit when I was collecting data and ensured that colleagues felt comfortable with the data collection. Asking for consent at each stage of data collection was paramount as well as member to make sure I had accurately represented colleagues' words and thoughts. Finally, reflexivity of the data collection process was necessary to reduce bias.

The risks associated with this research were minimal; however, I was conscious that negative emotions surface during interviews and observations. Participants were given the choice to not answer any question or participate in any aspect of the research process that made them uncomfortable. Relationships between researcher and participants is a central issue within feminist research because the researcher occupies a more powerful position (Olesen, 2018). Therefore, it was important to consider and involve the community in which the research was carried out (Lincoln, 1995). Lincoln also advocates for reciprocity and sacredness when conducting research. Reciprocity puts the person in the center of the research and sacredness means giving participants dignity and justice throughout the research process (Lincoln, 1995). Consideration of voice, being reflexive and subjective, and giving back to the community are key ethical issues as well (Lincoln, 1995). The leaders at the high school have asked me to share my research findings to better inform stakeholders of their mathematics philosophy as well as feedback from teachers on their feelings with the coaching, feedback, and evaluation processes, among other matters. Making these goals central to my research provided a community-centered and person-centered approach to this research. Consent, confidentiality, secured data, and community-centered research ensured that high ethical practices were implemented in this research.

Summary

The prevalence of traditional teaching methods in mathematics education and the lack of research examining the relationships between administrators, mathematics leaders and mathematics teachers in supporting ambitious mathematics practices led me to conduct this study. The purpose of the study was to describe and interpret the work of

school leaders with mathematics teachers at a large, suburban public high school and addressed the primary research question: How do the relationships between administrators, mathematics leaders, and mathematics teachers at the high school support change toward ambitious mathematics practices? To address this research question, I used a case study approach to describe the relationships between school leaders and mathematics teachers at the high school. Case study was the appropriate approach to answer my research questions because of the large amount of data that can be collected and the descriptive power of the particular within a single case study (Stake, 2003). Data collected included school leader interviews, teacher interviews, observations, participant-observations, and artifact and document collection. Data were analyzed through an eclectic coding process that created naturalistic generalizations as outlined by Creswell (2013) and Saldana (2016).

CHAPTER 4: FINDINGS

The findings are divided into six sections: 1) setting the stage, 2) participants' views of mathematics instruction, 3) the relationship between administrators and mathematics teachers, 4) the relationship between mathematics leaders and mathematics teachers, 5) the relationship between administrators and mathematics leaders, and 6) the areas in which the three relationships overlapped.

Setting the Stage

The school year started off like any other school year. At the beginning of August, about 140 teachers returned to school eager for classes to start. I was anxiously starting my tenth year as a teacher being new to the building and new to teaching high school. On my first day, I remember highlighting a particular passage from an article the principal asked us to read:

When educators share a sense of collective efficacy, school cultures tend to be characterized by beliefs that reflect high expectations for student success. A shared language that represents a focus on student learning as opposed to instructional compliance often emerges. The perceptions that influence the actions of educators include “We are evaluators,” “We are change agents,” and “We collaborate.” Teachers and leaders believe that it is their fundamental task to evaluate the effect of their practice on students’ progress and achievement. They also believe that success and failure in student learning is more about what they did or did not do, and they place value in solving problems of practice together (Donohoo et al., 2018, pg. 42).

This passage kept coming back to me throughout the school year as I started to learn more about the department culture. I revisit this quote again in the discussion.

I spent my first month establishing relationships with my new co-workers, learning the new curriculum, and getting a general feel for how both the school and the mathematics department operated. Though I was also a researcher, I wanted to be seen as a teacher first, showing the same work ethic that I brought to my previous teaching positions. I was nervous about giving anyone the wrong idea that I was just there to complete my dissertation. I quickly fell into a groove with my new co-workers, although learning the Interactive Mathematics Program (IMP) curriculum was more work than I anticipated. I often stayed at school hours after the final bell to make sure that I had thought through groupwork, the questions I would ask, and how I would structure presentations. This often meant that my data analysis was pushed aside until the weekend or the next break.

I was learning a lot and felt right at home with both my plan team and my department. The other mathematics teachers were friendly and always willing to offer help. Within the school, I immediately felt like I had a support network of people that I could ask for help—the teachers in the department, the mathematics department chair, the coach, the school instructional coach, and my evaluator. I began to collect data about a month into school — around September, just as fall formal observations were beginning. Everyone was gracious about allowing me to be a part of the pre- and post-observation conferences. A month or two later, I conducted the first of my interviews. School chugged along as normal until the week before spring break when concerns about the COVID-19 virus became more apparent. One week of online teaching after spring break turned into a month and, we never returned to school. Despite not physically being

in the building, plan teams, weekly department PLC meetings, and my data collection were able to continue over Zoom.

This wasn't the only uncommon thing about the school year. A revamp of the state standards came from the Department of Education in addition to the implementation of graduation competencies that would be enforced for next year's graduating senior class. While these graduation competencies allowed for flexibility with at least 12 ways to meet this competency, the focus for this high school was on SAT scores. Every junior in the state took the SAT, and this high school had the lowest SAT Math scores compared to all of the other traditional high schools in the district. One option for meeting the Graduation Competency was a score of 500 on the SAT Math Test. With an average Math score of 510 (where the district average was 543), only 57% of students were on track to meet this competency (compared to an average of 70% for the district). Pressure from the district to raise SAT scores inevitably came with this "last place" label and provided a unique backdrop to my research: How can ambitious mathematics practices be supported in the face of school reform? And this backdrop would permeate my data collection throughout the year [Fieldnotes, August 20, 2019; April 13, 2020].

Background of the Department

The mathematics department at this high school was unique because of their commitment to ambitious mathematics practices and the Interactive Mathematics Program (IMP) Curriculum. Veteran teachers in the department emphasized the almost 15-year process that it took to get to where the department was today. This involved the work and consistent dedication of many teachers and advocating to the administrators for structures to support professional learning. I have to acknowledge that research

completed over the course of the school year does not capture that full history. The department worked to integrate teachers into the culture through student teaching and a unique hiring process to find teachers who shared common beliefs about mathematics education. Additionally, teachers were recruited specifically because they had backgrounds in teaching IMP dating back to the 1990s. Cam, the mathematics department chair, served as an outreach coordinator and professional development consultant for the IMP curriculum for almost 20 years. In this section, I describe the unique nature of this department including the shared goals and the division within it.

Shared Goals

While there was a wide range of views about the shared goals of the department, most participants described goals supporting ambitious mathematics practices. Some participants claimed that there was a vision statement somewhere but did not remember what it said. The adopted vision for the mathematics department states that we “[believe] in a culture where students investigate problems and transfer mathematical knowledge to make sense of the world around them. By fostering a growth mindset, students become problem solvers who exhibit confidence, curiosity, and grit” (Mathematics PLC Agenda, August 2019). The responses from mathematics teachers, mathematics leaders, and administrators reflected this adopted vision statement and focused on four areas: the curriculum and tasks, math as a sense-making subject, developing student skills and dispositions, and agency.

Most participants discussed goals related to the curriculum and tasks. Several participants discussed the importance of an engaging curriculum that focused on contextual learning and relevant situations. One administrator stated:

I think every teacher in the math department wants to create engaging, relevant, and sustainable math experiences for their students. I think they've seen, either as students themselves or as teachers, the limitations of isolated approaches [to mathematics] and they just want students to see mathematics in their lives... But I think a shared vision is that we want students... to like math. Universally, we want students to be engaged and see math in their lives.

Most participants discussed the importance of a relevant curriculum that allowed students to think deeply, develop a conceptual understanding, and enjoy math.

Second, participants emphasized the importance of math as a sense-making subject and supporting conceptual knowledge. Participants wanted students to understand the *why* behind the mathematics they were learning and not just memorize and follow procedures. Participants emphasized that this goal was not common to most schools and acknowledged that it was something that they wanted to continue to work toward as a department.

Third, participants focused on developing student skills and dispositions as a goal for the department. Participants stressed the importance of students collaborating and communicating their thinking and developing perseverance, confidence, and a growth mindset. One teacher, Shay, discussed seeing these themes of collaboration and confidence in developing student dispositions: “We want to get students comfortable working through problems that are difficult and feeling more comfortable not knowing something at first and somehow having the confidence that with enough time and effort they can get it.” The area of developing student skills and dispositions was discussed most often by participants (8 out of 10 participants).

Finally, participants emphasized student agency; they wanted to see students engaging in productive struggle during math, taking ownership of their work, and building themselves as learners and problem solvers. Creating a culture of presentations, whole-class discussions, and discussing students' work was one feature of classrooms that was common throughout the department. This was one aspect of the classroom that participants emphasized as a way to provide student ownership and agency. It was also something that many participants said that the department continued to work and improve upon. It is important to note that participants held common goals, even across role groups. Administrators, mathematics leaders, and teachers held goals of having an engaging curriculum, teaching math as a sense making subject, developing student skills, dispositions, and student agency. It is uncommon for a department to be as aligned as this one in supporting ambitious mathematics practices (Garner & Horn, 2018).

Division in the Department

Despite the shared goals, the existence of a strong divide between the department faculty, created tension and conflict. This department division was difficult to articulate. There were two distinct sides, which I will refer to as the "in-group" and the "out-group". The term "in-group" signifies cultural and political capital and identifies others as "one of us" with a shared identity. The in-group consisted of the IMP veterans in the department, including the mathematics leaders and many of the more veteran teachers who had been recruited to teach at the school due to their previous teaching experience with IMP. Participants in the in-group included Cam, Jesse, Blair, and Shay (although it is important to note that Shay showed disagreement at times in interviews and personal conversations). These teachers saw the IMP curriculum come and go at multiple schools

as a result of “giving an inch” to diverging from the curriculum. Because of their common background, the in-group teachers believed that the prescribed instructional strategies and IMP curriculum lead to great teaching. The IMP veterans were frustrated when teachers tried to change or amend the curriculum through content delivery or supplementation. They expressed fear that with a change in the curriculum, ambitious mathematics practices would quickly begin to deteriorate. The curriculum was the engine that drove the instructional practices and philosophy of the department. Furthermore, Cam, Blair, and Jesse emphasized that deviating from the curriculum was a result of teachers lacking a strong content knowledge and an unwillingness to put in the hard work and commitment required by the curriculum.

On the other side of the argument, the out-group teachers included the administrators and teachers who were newer to the school. The participants in the out-group included administrators Alex, Jamie, and Andy as well as teachers Taylor, Riley, Jordan, and eventually me. The out-group did not have the same background and experience with IMP and were not trusted by the in-group. However, they also believed in the core ideas of mathematics instruction at the high school and valued working at a place where ambitious mathematics practices were part of the culture. They believed in the same instructional strategies as the in-group teachers and also strived to implement groupwork, strong classroom discourse, and presentations into their classrooms – which were the foundations of the IMP curriculum. In contrast to the in-group, they also saw a need to balance procedural fluency with conceptual understanding, held different ideas about how best to deliver the content, and questioned the curriculum as the sole resource. These teachers and administrators were concerned that the curriculum was outdated and

did not align to the current standards, research, or needs of students. The out-group advocated for flexible content delivery and brought up concerns about students' concept development, mastery, and test performance.

From my perspective as a new teacher, it was difficult to navigate the commitment to the curriculum. I constantly felt like there were many conversations that required a sort of experiential knowledge of the lessons and activities. The in-group had developed this experiential knowledge through their experience with the IMP curriculum but it was not always made explicit for someone new. Teachers need to understand the connections between units, the right questions to ask during discussions to bring out the intended learning, and when to follow or amend the teacher's guide. It seemed the in-group teachers knew how to adapt the curriculum to meet students' needs, but did not always have these conversations during plan teams. The out-group saw that students needed something different, and so they tried to supplement the curriculum. I noticed several examples of fear and judgement from in-group members when a teacher tried to supplement, change, or amend lessons when they felt that students needed a little more practice with a topic. It was common knowledge among out-group teachers not to leave non-IMP worksheets out in the open, on your classroom desk, or on the copy machine. The in-group saw these deviations as a way to bring down the cognitive demand of the curriculum; however, this was not the intent from out-group teachers. The typical response from in-group members was to "trust the curriculum" instead of engaging in conversations to support these teachers in better meeting their students' needs.

The administrators and mathematics leaders felt that it was important for all teachers to understand and be aligned with the department's philosophy. Jamie shared his

views about the importance of philosophical alignment in showing unity against criticism the mathematics department received:

Our math department is probably the most criticized group in the school... But I think because of that criticism, we've had to get aligned and our teachers have to be on board with each other and have to be pulling the same direction because as soon as people start dropping off and good cop/bad cop each other, the whole thing would fall apart real quick. So I think it's important that we put so much work and effort into getting people to understand the philosophy and the why we do what we do. It's hard to be the odd bird, everybody says you're doing it wrong because you're different.

Stakeholders, including some administrators, district leaders, and community members (parents) often blamed the teaching practices of the mathematics department or the IMP curriculum for low performance and low test scores. Therefore, administrators and mathematics leaders saw the importance of philosophical alignment and maintaining commitment to the curriculum as a way to show unity to different stakeholders.

The department division emerged as a major theme and will be discussed throughout the findings. All participants commented on the department alignment as a challenge. Taylor described the lack of alignment between two sides of the department:

I think working in this specific math department can be really challenging because I feel like we are very divided, almost half and half. There's a lot of fear in the department I think on both sides. I think fear from the veteran teachers that IMP will eventually disappear and then fear from the newer teachers because sometimes [they're] afraid to implement certain practices in [the] classroom that

would best benefit students without being yelled at for it, disciplined, or judged by other teachers. So, I think there's a lot of fear fostering there.

Out-group participants discussed the effects the department divide had on their day-to-day experiences, including feeling judged by in-group teachers. For example, Jordan recalled feeling judged when she asked for help with the curriculum:

There are some teachers I know I can go to for anything, whether it's for personal [reasons] or just to get help with the curriculum. And then there are others that I absolutely will not go to because I feel like I'm judged or if I ask them a question or [for] help with something, they just run and tell their math friends.

Similarly, Riley discussed the effect of the division on themselves as a teacher, saying that it is hard to focus on yourself and your needs as a teacher instead of focusing on the conflicts happening within the department. It was surprising that these divisions existed given the strong alignment between participants' expressed goals for the department and that teachers on both sides of the divide were committed to implementing the same ambitious mathematics practices.

Participant Backgrounds

The mathematics teachers, mathematics leaders, and administrators all brought unique backgrounds to their roles. In the mathematics department as a whole, I was the only mid-career teacher. The in-group participants included a veteran teacher, Blair, who was one of the first mathematics teachers at the school. She played an integral role in implementing the IMP curriculum, structuring the schedule to allow for plan teams, and hiring the current teachers in the department. Jesse, the mathematics department chair, was a former instructional coach and while Cam, the mathematics coach, had only two

years of teaching experience, she had extensive experience in professional development with IMP as I previously mentioned. The out-group teachers included Jordan, a former middle school principal and a district administrator with experience providing professional development with Algebra 1 teachers. The newer mathematics teachers were drawn to the philosophy of teaching at the high school. For example, Shay compared it to his last school that was more traditional and felt that his views of mathematics instruction was more aligned with this department.

It is rare for administrators to understand and support the goals of ambitious mathematics practices (Burch & Spillane, 2003; Nelson, 2010). Each of the administrator participants (principal, assistant principal, and dean) had been at the school since the first few years of opening (around 12 years). Although neither of the administrator participants had taught mathematics, their experience at the school provided a unique view of the mathematics curriculum and the department. For example, the principal's background was English/Language Arts and Theater, but he developed his awareness of great mathematics instruction from watching great mathematics teachers and working closely with district leadership. The assistant principal, Jamie, was part of the history of the IMP curriculum since the school opened and worked with mathematics leaders to ensure effective planning teams.

The dean, Andy's, experiences in working in an interdisciplinary office and interacting with teachers from other departments increased his knowledge of mathematics instruction. In many high school settings, teachers are often organized into content-specific departments and share offices or classrooms with those departments in order to promote standardization and efficiency (Tyack & Cuban, 1995). This high school's

academy model organized teachers into interdisciplinary pods and shared offices with their interdisciplinary academy team. The division — by academy instead of by department — provided teachers with opportunities to discuss and understand what was happening in other classrooms and departments and also provided opportunities to collaborate. Prior to becoming an administrator, Andy taught science in an academy and developed a passion for interdisciplinary planning with one of the mathematics teachers. All the administrator participants previously worked as teachers in these academies which contributed to their knowledge of the mathematics department goals, an experience most administrators do not have at other schools.

Summary

Three important points are worth stating to close this section because the background of the department differed from typical high school mathematics departments in several ways. First, several veteran teachers made a long-term commitment to develop a culture of ambitious mathematics practices, including recruiting and hiring teachers aligned with the department philosophy. Second, the goals of the department consistently supported ambitious mathematics practices. Furthermore, administrators supported these department goals. These common goals can be traced back to interdisciplinary teacher interactions, a feature also not typical in high schools. Finally, despite these common goals and commitments to ambitious mathematics practices, a divide existed in the department that caused tension and conflict. The test score and graduation competency conversation both added to the tension between in-group and out-group participants and hindered conversations around instruction. In the next section, I discuss the views of mathematics instruction more in depth.

Views About Mathematics Instruction

I am sitting in one of my first plan team meetings with my new colleagues trying to wrap my head around our first Math I unit, “Patterns”. Because I am one of the new teachers, I always try to come into a new role listening more than sharing. We discuss the big ideas, the concept of a function, and developing ideas of different ways to represent those functions. With this conversation, my mind immediately goes to a series of lessons I developed when teaching 8th grade that I know would fit this context, where students explore the idea of Caesar ciphers, the Enigma Machine, and make connections to the model of a function machine. I decide to bring it up and I immediately feel that I should have probably kept my mouth shut. My idea is met first with some awkward silence followed by, “that might be a good idea to think about if you have some extra time” from Cam, the coach. I sit back and listen for the rest of plan team meeting but still use a couple of activities in my classroom anyway because I know that this lesson incorporates ambitious mathematics practices.

About six months later teaching Math II, I am introducing a lesson on Pythagorean Theorem and its converse to my class and Cam walks in for a surprise observation. My stomach drops and my throat catches. I start to stumble over my words because I don’t know what I am going to do. I spent hours the past week adapting this Pythagorean Theorem lesson from the textbook with my plan team partner, Riley and I just got caught. In the original lesson, “Tri-Square Rug Game”, the context presented to students is that Al and Betty are dropping darts on a rug that models an illustrated version of Pythagorean Theorem, with an a^2 , b^2 , and c^2 rug. I just could not fathom using this context in my classroom; it was too out of touch with any real world situation.

Bruner (1960) discusses the idea of “intellectual honesty” where learning experiences are both responsive and responsible, connecting them to the ideas and traditions of mathematics (Ball, 1993; Bruner, 1960). In my mind, this lesson was not intellectually honest. I adapted the lesson to build on students’ prior knowledge that I knew they were coming with from middle school, focusing on building the idea of the Pythagorean Theorem converse, exploring in groups by building triangles out of three different sized squares and classifying them as acute, right, or obtuse triangles, ultimately meeting the same goals outlined in the original lesson.

As I stand there in front of my class with my mind racing, I cannot abandon my plan now knowing that I will get reprimanded for it later, so the lesson goes on. Throughout, while my heart races and I cannot keep my clammy palms dry, I can see the discontent on Cam’s face. But I am enjoying the conversations I am hearing from students and we have a pretty good discussion at the end of the lesson. After the class files out and my advisement students file in, Cam hangs back in the corner. While my advisement works on homework, she decide to give me feedback right away. As I suspected, Cam was not pleased. I panic and I lie to her, saying that we did that activity yesterday, but she knows. She tells me the reason behind the context, connecting to a Math I lesson on probability and the importance of the characters in the story to help students make connections across different topics. I get the idea but not the rigidity. My goals are aligned with theirs, so why am I not able to adapt the lesson to my students’ needs? A week later, I stop by her office and confess that I lied about the lesson and apologize for not being honest up front (Fieldnotes, August 20, 2019; March 3, 2020).

This excerpt highlights my experiences with the tensions between the in-group philosophy and out-group philosophy. While I know that Cam and I shared similar goals for instruction and for students' learning, our approaches were clearly different. In this section, I discuss the findings from coding both interview and observation data using the Vision of High-Quality Mathematics Instruction (VHQMI, Munter, 2014) and the Views of Students' Mathematical Capabilities (VSMC, Jackson et al., 2017). These two protocols give a deeper understanding of teachers' philosophies and beliefs about instruction.

Visions of High-Quality Mathematics Instruction

Overall, study participants—including administrators, mathematics leaders, and mathematics teachers—held sophisticated visions of high-quality mathematics instruction (Munter, 2014). In Table 4.1, I summarize participants' overall codes for the Visions of High-Quality Mathematics Instruction (VHQMI) rubric in the role of the teacher, classroom discourse, mathematical tasks, and student engagement. Each category in the VHQMI rubric was based on a score out of four points, where scores of a 3 or 4 (or a 2 for student engagement) indicate a more sophisticated vision of mathematics instruction. This analysis of participants' VHQMI scores highlight again how unique the mathematics department at this school is. Except within a couple of examples, scores in this area were consistently high across all participants. It is uncommon for sophisticated visions to be consistent across a department and even more rare that administrators without a mathematics background also held sophisticated visions of high-quality mathematics instruction. Furthermore, it is important to note that scores were not easily divisible among in-group and out-group participants.

Table 4.1*Participants' Views of Mathematics Instruction*

Role		VHQM			Eng.	VSMC	
		Teach. Role	Class Discourse	Math Tasks		Diagnostic Frame	Prognostic Frame
Admin	Alex	3	3	3	2	Productive	Mixed
	Jamie	3	3	-	2	Productive	Mixed
	Andy	3	2	-	2	Mixed	Productive
Math Leader	Cam	4	4	4	2	Mixed	Mixed
	Jesse	4	3	-	2	Productive	Productive
Teacher	Shay	3	3	3	-	Productive	Mixed
	Taylor	4	3	3	2	Productive	Mixed
	Blair	4	4	3	2	Productive	Mixed
	Riley	3	3	-	-	Mixed	Productive
	Jordan	3	3	1	2	Unproduct	Mixed

Note. Dashes indicate insufficient data to provide a score. Engagement (Eng.) provides a score out of 2.

Participants tended to focus on the role of the teacher and classroom discourse when asked about their views on mathematics instruction. Both in-group and out-group teachers held common views about the teachers' role and emphasized the importance of creating an environment that is student-led where the teacher facilitates learning, and students work in groups, ask each other questions, and participate in whole-class presentations or discussions. Participants most often described the role of the teacher, classroom discourse, and mathematical tasks at a level three. They commented on the teacher as a facilitator of student discovery, including posing problems and asking students to describe their strategies and avoiding telling students too much during the discovery process. Furthermore, they discussed whole class conversation and students asking each other questions but typically the teacher was still at the center of the

discussion. These instructional features were all characteristics of ambitious mathematics practices (Munter, 2014).

One out-group teacher, Taylor, joined the in-group participants in describing the teacher's role at a more sophisticated level, where the teacher facilitates an environment in which students are given greater mathematical authority and the teacher has a responsibility to intervene and scaffold students' ideas — the function of the discourse community (Munter, 2014). Blair, an in-group veteran teacher, elaborated on Taylor's ideas of the teachers' role:

I listen specifically to the kids, I listen to the questions they ask, I watch what they do when they're stuck, I watch what they would do when they're confused. How do they solve it? What kind of conclusions are they drawing? And then I watch how does the teacher respond to all of those things that are happening? Do they listen to student ways of thinking about a problem? Do they honor non-traditional, maybe non-expected, or unexpected ways that kids think about a problem and really weave those in? Do they create a culture where kids are responding to kids and listening to each other or does everything run through the teacher?

Blair's description reflects a vision where the teacher's use of students' questions and ideas as content for the lesson provides them with mathematical authority as they are positioned as leaders and decision-makers in the classroom. These classroom structures support a mathematical discourse community (Munter, 2014).

While administrators provided similar visions for classroom instruction, they were less mathematically specific. Jamie described whole group discussions this way:

I think the hardest part is that two or three students take over the class and are always the ones providing examples, who are looking to participate as much as they can. That for the teacher to recognize that maybe not every kid is getting involved, how do I get more kids involved in those discussions? I think also you're looking for the kinds of questions that kids ask too. Can they answer teachers' questions but then are they really engaged, asking good questions and that's how you know you have that really high level of thinking, they're questioning stuff.

In this example, Jamie describes the teacher's role in involving students but does not detail specific strategies, nor what good questions would look like. All three administrator participants provided similar descriptions where they discussed the importance of high-quality mathematics instruction, engaging students in mathematics, and high-level thinking. While their comments showed a sophisticated level of instruction, they were not as specific as mathematics department members were. As a result, their scores warranted a three instead of a four.

Views of Students' Mathematical Capabilities

Part of achieving a vision of high-quality math instruction is the belief that all students are capable of engaging in rigorous mathematics and contributing valuable ideas to a class discussion (Jackson et al., 2017). Jackson and colleagues differentiate between *diagnostic* framing, which emphasizes the sources of students' struggles in mathematics and *prognostic* framing, which concerns how teachers address these struggles with students. Both framings are coded as *productive* if they center students' struggles in regard to instruction or schooling opportunities and aim to support students to participate

in rigorous mathematics, while an *unproductive* frame centers students' inherent traits or deficits in community or family background and aims to reduce the rigor of learning for certain students. A *mixed* code indicates that participants wavered between productive and unproductive frames – describing students' performance as a combination of educational opportunities and inherent traits or background. Study participants described features of both productive and unproductive frames.

Diagnostic Frames. For most study participants a majority of the diagnostic frames were productive or mixed; only one teacher held an unproductive frame (see Table 4.1). There were several similarities between participants' responses and only a few statements framed student struggles around their inherent traits or family backgrounds. Participants' unproductive statements included descriptions of students "wanting someone to bail them out or just give them the answer," absences, having other priorities other than math class, taking advantage of, or blaming the fact that they were on a special education plan, learned behavior of deflection, or reading level. However, these statements were often accompanied by more productive frames, leading three participants (Andy, Cam, and Riley) to have a mixed diagnostic frame.

Most of the participants held a productive diagnostic frame as they acknowledged students' previous experiences and beliefs about their mathematics ability as a source of struggle. For example, Jamie described students' beliefs about their mathematics abilities and their confidence arising from previous school experiences (Jackson et al., 2017). A few participants connected students' academic gaps in mathematics to previous teachers. While these are considered productive frames as blame shifts focus away from students' inherent traits, they still highlight students' backgrounds as the source of struggle. Alex

also discussed relationships in the classroom, specifically that when students do not feel valued in the classroom they feel more vulnerable. Alex believed that positive relationships with students support students' grappling with new concepts in mathematics. In these examples, both Jamie and Alex examined the instruction and culture in the classroom without placing blame on the students.

Several participants also reflected on their own teaching. Administrators and mathematics leaders were more likely to discuss aspects of the teacher's instruction as a source of struggle for students. For example, Jesse, the department chair, explained:

From the teacher perspective, I would say maybe the activity isn't appropriate for the time or the rigor is off, there isn't a response to the kids' struggle. Like maybe I need to slow down, maybe I need to come up with another way to introduce this topic. So there's not responsive teaching, there is more like, "Well I taught it, they didn't learn it, not my problem." What data do you have that you are ready to move on? I look for the culture in the classroom. Has a culture been set up embracing learning and disequilibrium and questioning and celebration and support and risk taking? And I think you can tell whether that's been tended to or not in classrooms.

Here, the mathematics department chair discusses the importance of responsive teaching and the teacher's responsibility to establish a classroom culture that supports student risk-taking. In both cases, focusing on students' background and teachers' current instruction as sources of struggle are productive dispositions because they position students as capable of achievement in mathematics and the need for instruction to ensure the success of all students. Overall, there were similarities in statements between administrators,

mathematics leaders, and administrators and also across in-group and out-group participants. Responsive teaching and classroom culture, the relationship between the teacher and student, and feelings of safety were common examples of statements made.

Prognostic Frames. A *productive* prognostic frame provides supports for struggling students to participate in rigorous mathematics, while *unproductive* frames focus on providing supports that reduce the rigor of the task or activity that students are engaged in (Jackson et al., 2017). A *mixed* frame incorporates prognostic strategies that are both productive and unproductive. Seven of the ten participants held a mixed prognostic frame (see Table 4.1). One administrator (Andy) and one mathematics leader (Jesse) held productive prognostic frames, mentioning scaffolding and differentiation while acknowledging the harm that these can sometimes cause for students. For example, Jesse described a pattern of “scaffolding” that she saw happening in classrooms:

I think scaffolding has been sort of a bailout. Like, “Well I scaffolded it for the struggling students,” and a lot of times that sends a message to a kid that you can't do it and it takes the thinking away. We want kids to learn how to think and how to learn and how to problem solve and sometimes the scaffolding approach to differentiation can have a negative effect.

Andy discussed the importance of differentiation that does not reduce the cognitive demand, showing a productive prognostic frame. Both Jesse and Andy questioned how well-planned the differentiation is for teachers. Their comments acknowledged teachers' efforts at scaffolding or differentiation, but question whether differentiation was actually supporting students in engaging in rigorous mathematics instruction.

Statements characterized as unproductive that led to participants having a mixed prognostic frame focused on simplifying assignments for certain students, providing leveled assignments, or believing that some students should work on additional assignments or work ahead in the curriculum in order to be challenged. These examples were common and positioned some students as incapable of participating in the same rigorous activities as their peers. However, these participants also provided many examples of productive supports for struggling students, the most common being different grouping strategies, knowing students and how they learn, and making sure that presentations and group discussions shared multiple strategies for solving problems. In these examples, the teachers described providing support for students to participate in rigorous mathematics without reducing the expectations of the task for those who were struggling.

Summary

In summary, study participants shared a belief system that aligned with ambitious mathematics practices and were not divided between the in-group and the out-group members. It is significant to note that it is rare for scores to be consistently high across both the department and administration (Garner & Horn, 2018) and for the department members to show strong alignment in their beliefs and visions. These trends provide a strong foundation and capacity for instructional improvement, ambitious mathematics practices, coaching, and teacher learning. However, given the strong philosophical alignment in the department, it is remarkable that there was division in the department that significantly affected the culture. It is also unusual that the alignment in beliefs about mathematics instruction did not create more trust between the mathematics department to

adapt the curriculum or a lesson like the “Tri-Square Rug Game” to better meet the needs of their students while still maintaining a commitment to ambitious mathematics practices.

Administrator/Mathematics Teacher Relationships

As I stood outside of Andy’s office waiting for my post-observation conference to start, I was nervous. I was clutching my computer awkwardly and standing in an inconvenient spot of a narrow hallway in the office. Teachers and other administrators were buzzing back and forth but there was not a better place to stand. Andy was running a few minutes late. The anticipation of how this would go was making my breathing shallow. I had been in this situation many times before at previous schools, where I thought my lesson had gone well but my evaluator would find little things in my class to point out. “That group in the corner was off-task,” or “Why didn’t you say anything to the kid with the cell phone?” or “I think you should put your desks in rows — your students can’t handle groupwork.” So how would this one go? I sat down in his office, opened my computer, and glanced around the room. There were pictures of family, a few teaching awards, and relics from a past career as a sheriff. Although my palms were sweaty, I was ready and open for feedback. I am always ready to improve and improve my practice, but also have some things that I am ready to share. I scan through my notes again. I did not have much time to review them prior to the meeting, but I am anxious to get a sense of good or bad.

Andy recaps my classroom through his experience as an observer. The tense feeling in my shoulders softens. As he tells the story of my class, he shares things he likes and some things to think about. “How could the problem be approached differently?

What if you tried this?” He plays audio from my room, the quiet buzz of students working. He comments on the girls dancing, “They were super comfortable dancing and speaking Spanish, listening, but still engaged in the problem. They were thinking and dancing at the same time... but I’m in different rooms and they’re just very comfortable but not out of control.” My goals and vision are seen, but I still receive feedback to take my vision closer to reality. I feel comfortable enough to be honest and share frustrations I have been feeling as a teacher – a lack of freedom to change lessons or having my ideas shut down in plan team meetings. He listens attentively from a place of understanding. When I leave the office to go teach my next class, I finally feel like I am in a school where I am understood as a teacher. (Fieldnotes, October 24, 2019)

For many teachers (including myself), evaluation meetings can be a stressful situation. A trusting relationship with the administrator who understands the teacher’s or department’s goals in the classroom is important. Administrators and mathematics teachers’ predominant interaction was through the evaluation process. Most mathematics teachers did not have other interactions with administrators besides making small talk in the hall or the occasional pop-in to classrooms. In this section, I focus on the teacher evaluation process, the feedback that mathematics teachers received from administrators, and mathematics teachers’ feelings of support from administrators.

Teacher Evaluation Process

Administrators’ standard observation protocol comprised a pre-observation conference, a full class period observation, and a post-observation conference. The school was required to follow the district’s standard evaluation rubric containing five categories, on which teachers were scored from a level 1 to a level 4. The five categories included:

Culture and Climate, Professionalism, Planning, Assessment, and Instruction. Safety of students and the goals of the school (rigor, relevance, and relationships) were a top priority for observations. While the rubric was a general evaluation tool for all teachers and therefore did not address mathematics instruction specifically, it did not contradict the aims of ambitious mathematics practices. For example, under the Instruction category, level 4 rating criteria included language such as: “the teacher encourages learning through inquiry and intentionally guides students to use higher-order thinking skills” and “the teacher guides students to take risks using both formal and informal feedback” (District Evaluation Rubric). The evaluation rubric could still be used as a tool for administrators to support ambitious mathematics practices through feedback. In this section, I discuss the logistics of the evaluation process, the typical structure of the pre-observation conference, and the observation and post-observation conference.

Administrators varied in how many teachers they evaluated with the principal and assistant principals each evaluating 25-30 teachers and deans about 10. Alex noted that it was the goal for each evaluator to have at least six points of connection during the year that included formal observations, 15- to 20-minute classroom pop-ins or observing plan teams and PLC meetings. This allowed administrators to collect a variety of data for the evaluation process. Teachers who had been in the district less than three years were formally observed once in the fall and once in the spring, while all other teachers were observed only once (either fall or spring). The administrators’ large observational load and other job responsibilities, meant that they did not visit classrooms as often as they wanted. Alex and Andy referred to this as the “tyranny of the urgent”:

This job, I spent a lot of my time in things other than evaluation of teaching. I get blown off course. Stephen Covey calls it the “tyranny of the urgent” and I appreciated that. The tyranny of the urgent sometimes dictates my calendar where I would love to spend more time in classrooms than I do but I also have a responsibility to other stakeholders... So with the multitude and myriad of tasks that hit my calendar in a given day I wish more of them were spending time in classrooms.

Like Alex, Andy also commented on the challenges of balancing other responsibilities with being in classrooms: “I sometimes don’t feel like I’m always present enough to be able to be in the environment as much as I want to.” Teachers recognized this as well, understanding that administrators were stretched thin and would most likely come into classrooms more often if they could. Most of the mathematics teacher participants stated that administrators did not visit their classrooms for observations or pop-ins during the year other than as their evaluator.

All administrators invited me to observe the formal observation process and I observed six pre- and post-observation cycles in addition to participating in one of my own observation cycles. In the pre-observation conference, administrators asked about where the lesson fell within the sequence of the curriculum, how the teacher was anticipating students’ thinking and their plan for differentiation, keeping students engaged, and how they would assess students’ learning. During the observation, administrators took notes but often sat and interacted with students, working with them on problems and asking them questions about their experience in the classroom. However, administrators were aware of and made comments about how their presence

changed the dynamic of students' conversations. A few mathematics teachers treated the administrators as students, asking them questions and calling on them for answers.

For the post-observation conference, the content and focus of the conversation varied among administrators more than the pre-observation conference. For example, Alex asked more questions than the others, allowing teachers time to reflect. Jamie kept his comments short and to the point; his post-observation conferences were relatively brief. Even though Jamie held shorter post-observation conferences, mathematics teachers commented that they sought Jamie out for advice often outside of the evaluation process. Andy embedded appraisals and suggestions within a narration of his experience within the classroom and then spent time asking questions. I describe the types of feedback given during the post-observation conferences next.

Types of Feedback Received from Administrators

Administrators provided three forms of feedback to mathematics teachers: appraisals, questions, and suggestions. An appraisal was an administrator's remark indicating that they liked something they saw or if they made a comparison to what they have seen in other classrooms. Questions came in a variety of forms from general reflection questions to rhetorical questions that were intended to provide feedback or a suggestion to the teacher. Suggestions were more straight-forward feedback given to the teacher; they were intended to provide a strategy for the teacher to implement or potentially something to avoid.

Feedback was coded as mathematically specific if it addressed one of the eight categories of the *Principles to Actions* Mathematics Teaching Practices (Leinwand et al., 2014) or fell on the VHQM (Munter, 2014) or VSMC (Jackson et al., 2017) rubrics.

Feedback was general or other if it addressed teaching practices like classroom management or was specific to the goals of the teacher (for example, one teacher asked for feedback specifically on direct instruction). The types of feedback I discuss include appraisals of culture, norms, and expectations and administrators' mathematically specific feedback.

Table 4.2

Types of Feedback Given by Administrators and Mathematics Leaders

		Forms of Feedback					
	Appraisals:	%	Questions:	%	Suggestions:	%	Total
Admin	CNE	44.6	CNE	11.2	CNE	10.5	34.2%
	Engagement	14.6	Reflection	29.6	Engagement	0	---
	General	21.4	General	29.6	General	47.4	26.2%
	Math-Specific	19.4	Math-Specific	29.6	Math-Specific	31.6	24.2%
	Total (103)	69.1%	Total (27)	18.1%	Total (19)	12.8%	
Math Leaders	CNE	14.8	CNE	8.3	CNE	4.5	9.8%
	Engagement	18.5	Reflection	8.3	Engagement	13.6	---
	General	14.8	General	25.0	General	9.0	14.8%
	Math-Specific	51.9	Math-Specific	58.4	Math-Specific	72.7	60.7%
	Total (27)	44.3%	Total (12)	19.7%	Total (22)	36.1%	

Note. CNE refers to Culture, Norms, and Expectations.

Nearly 70% of the administrators' feedback came in the form of appraisals (See Table 4.2) which highlights their focus on acknowledging the positive aspects of teachers' practice. Forty-five percent of the appraisals were comments that addressed classroom culture, norms, or expectations (CNE) and were overwhelmingly positive. Climate and culture was one of the five categories on the evaluation rubric and was a priority for the school and for each administrator, as well. Alex commented on prioritizing student belonging throughout the school:

When kids come here, I don't care if they are 18 years old or 14 years old, they need to have a good time. And what that boils down to is they need to feel like they belong here and I just can't separate that from whether students are in a math classroom or walking down the hallway or walking in the door... then adequate and effective [instruction] really take care of themselves at some level... but what are you doing that day that kids are like, “I want to be in your class”?

Administrators understood the importance of climate and culture in the classroom when attempting to implement ambitious mathematics practices, and this was reflected in their feedback. Administrators frequently commented on the “vibe” in the classroom when discussing climate and culture. This was the most common type of appraisal provided. While this may seem disconnected from ambitious mathematics practices, developing a sense of belongingness for students is important particularly for students who have had negative experiences in mathematics classes (Horn, 2017).

Only about 25% of administrators’ feedback was mathematically specific and was evident most often in the questions that they asked and the suggestions they gave (30% for each category). Their most common questions and suggestions that supported ambitious mathematics practices focused on “eliciting and using evidence of student thinking” and “building procedural fluency from conceptual understanding” (Leinwand et al., 2014). Another common area of mathematically specific feedback was the encouragement given to teachers to build procedural fluency from conceptual understanding. For example, Alex encouraged teachers to build on the conceptual understanding that students gained in the classroom and provide opportunities for them to develop procedural fluency from that foundation. In summary, administrators only

provided mathematically specific feedback about a quarter of the time, and their predominant focus was on supporting culture, norms, and expectations in classrooms.

Mathematics Teachers' Views of Administrator Feedback

Views of administrator feedback fell mostly along the in-group and out-group division. Out-group teachers acknowledged that their feedback was rarely mathematically specific but still felt it supported their improvement. For example, Shay, described the supportive feedback he received:

What comes to mind here is the grading stuff that I was talking to [my evaluator] about. How can my gradebook be less focused on a letter grade and numerical percentages and scales when that's required by our district and our building?

These are conversations that spanned weeks into months based on one or two observations and just questions that I had. I see that happening all around. I think part of the reason why that conversation was so beneficial is because I did kind of approach [them] with those questions and because of that, I think [they were] really receptive and willing to work with me.

Taylor echoed these views saying that the conversations with administrators built confidence and pushed them to improve. Riley said that it always felt like a new challenge and something to be working toward. When asked about mathematically specific feedback she received, Jordan explained how administrators provided feedback on differentiation, groupwork, and student participation that still supported the mathematics content and goals of the department. While out-group teachers recognized that the administrators were not content experts, they found their suggestions of general teaching strategies helpful.

In-group teachers showed a level of distrust with the evaluation system, even though they showed alignment with goals and views of mathematics instruction. Jesse and Blair asked administrators to be data-collectors during their observation so that they could receive feedback that was more mathematics-specific and were less trusting of administrators to provide useful feedback. Blair expressed frustration that the feedback she received was surface level, since they did not have a background in mathematics. She described how she used the evaluation process:

I look at what is it that I'm frustrated about in my classroom, what is it that I want to improve on and then I craft the conversation in evaluation on what I want them to look for. I ask them to be data collectors for me... and then I will analyze that and I will make the appropriate adjustments to improve my instruction. So I have figured out a way where I can use the evaluation process to improve as a teacher, but I do it all basically myself and just use them as a data collector.

During their pre-observation conference, Blair asked Andy to collect data on the student experience in her classroom. Andy sat with a few groups during the observation and narrated, as best he could, how he experienced the class from the student perspective but also how students were feeling throughout the class.

Andy, however, felt that this made the conversation shallow. He explained that while administrators may not have teaching experience in one area, they had the capacity to be more than just data collectors. As a previous science teacher, Andy had an interest in instructional conversations in other content areas and enjoyed those most in his role as an administrator. Data collection limited the ability to have these deeper instructional conversations and to learn more about mathematics instruction. I sensed during my

interviews and observations with Jamie and Alex that they were interested in continuing to learn more about mathematics instruction.

Summary

To summarize, interactions between administrators and teachers happened primarily through the evaluation process. A majority of administrators' feedback focused on culture, norms, and expectations and were primarily appraisals. While administrators did not always give mathematically specific feedback, their feedback was still seen as helpful by out-group teachers. There were several examples of administrators' feedback being aligned to ambitious mathematics practices. I was appreciative of Andy's feedback, pushing me to think about different ways to approach the problem but still acknowledging that students felt comfortable in my classroom. In-group teachers, on the other hand were less trusting of feedback and found a way to use the evaluation process to improve their mathematics instruction. They requested administrators to be data collectors which limited the ability for administrators to have deeper conversations about mathematics instruction.

Mathematics Leader/Mathematics Teacher Relationships

I arrive a few minutes late to the plan team, and Cam, Shay, and Taylor are already sitting around the little circle table in the corner of the coach's office. I gently close the door behind me, trying to appear less of an intruder to a conversation I'm usually not a part of. I sit quietly at the empty chair and open my computer. I cross one leg under me. This office has always felt comfortable. I sat here long before I became a teacher at the school, when I was still trying to gain entry for research. I had been talking with the mathematics coach for a few years, eager to know more about the math

program. It already feels like forever ago, but I have the same familiar feeling that I had back then, the excitement to be a part of something new and different. The large curriculum map hangs on the wall with different colors of string showing the connections of big ideas from Math 1 to Math 5 and into Statistics and Calculus. I look at the books on the shelf and the whiteboard to my left — full of notes, math problems, and questions.

I bring myself back to the plan team meeting and my three colleagues' discussion of the visit from the new district math coordinator. I came here to observe, but I am genuinely interested in the conversation and I ask questions along with the other teachers. After a long discussion, the formal plan team meeting starts. While I attempt to fade into the background, clearly I have already made my presence more known than I usually do. The other teachers look at me when they talk; I feel like a part of the team. I listen intently and with interest as they discuss a math problem that I have not yet taught myself. I try to picture this particular lesson in the sequence of the curriculum and smile as I see the animation from all three of them. They mime putting their arms around trees, talk about ridiculous questions that students ask, and even have their own language— Shay describes the “waffle pattern” strategy from their class. He goes up to the whiteboard to demonstrate how to find the area of the circle as the others giggle. The meeting wraps up as they chat like old friends having coffee and just like that, it is time to go back to teaching our final class of the day (Fieldnotes, December 16, 2019).

This description of a plan team meeting was not my experience in all meetings. As a new teacher, I did more listening in my own plan team meetings and rarely shared my own ideas. It often seemed less collaborative than the vignette above and my role as an observer was similar. Plan teams (as detailed above) are one example of how Cam and

Jesse interacted with the teachers. Other interactions included Professional Learning Community (PLC) meetings, observations, and co-teaching. Because two individuals were in leadership positions within the department, they worked together to split the responsibilities so that they were both supporting teachers without overwhelming them. Jesse planned weekly PLC meetings and co-taught with teachers. Cam met weekly with each plan team and conducted observations in teachers' classrooms. While they divided responsibilities, they regularly communicated with one another and collaborated frequently to meet teachers' needs. Unfortunately, I did not collect as much observational data of interactions between mathematics leaders and mathematics teachers because I was not invited to observe many feedback sessions from observations and co-teaching opportunities. Therefore, in this section I rely primarily on interviews to discuss plan teams, observations and co-teaching, and the feelings of support mathematics teachers felt from mathematics leaders.

Plan Teams

Plan teams were the most consistent source of content-specific coaching for mathematics teachers. Plan teams were composed of between two and five teachers who taught the same course. The department chair created the schedule and decided who would be on a plan team, based on individuals' experience and strengths. In-group teachers were intentionally placed on plan teams to serve as leaders and mentors to their out-group colleagues and newer teachers. Plan teams met between three and five days a week during teachers' planning periods and the mathematics coach joined on one of these days. This time in plan teams was significantly more than typical teachers who, on average, collaborate for 2.7 hours per week (MetLife Foundation, 2009). The goal of plan

teams was to provide support to one another for upcoming lessons and as to discuss the curriculum. When the mathematics coach joined the meetings, the discussion focused on the instructional goals for the upcoming week. Using Graham and Ferriter's (2008) *Seven Stages of Collaborative Team Development Framework* and Horn and colleagues' (2017) *Taxonomy of Learning Opportunities in Teachers' Meetings*, I discuss the structure of plan teams more deeply.

Meetings began by "filling the time" conversations (Graham & Ferriter, 2008). This involved catching up, and discussing school politics or happenings, and other issues. "Filling the time" conversation then progressed to an overview of pacing within the curriculum, consisting of "sharing personal practice" (Graham & Ferriter, 2008) or "collective interpretation separate from future work" (Horn et al., 2017). Teachers spent a large amount of time sharing updates on where they were in the curriculum, how past lessons were taught, and presenting solutions of "could have done" or "should have done" (around 30 out of 60 minutes). During this time, future instruction was not yet discussed. From my perspective as a participant in these meetings, these discussions allowed me to be reflective but I often left the meeting frustrated that these recapping conversations happened after I taught a lesson instead of before.

After recapping and sharing personal practice, Cam discussed upcoming lessons; often focusing on the big ideas. For example, in the online plan team meeting, teachers were concerned about students not grasping the big ideas of the unit during online teaching (due to COVID-19). Cam provide this insight on upcoming lessons:

I think "Picturing Pictures" starts to [get at the big ideas]. The variables are a little easier to pull out, the constraints are a little easier to write, you can use those to

leverage like, “How would I graph that?” And I would go to the table... A lot of them will just pick a point on either side [of the line] to see which is true. “Where do I shade? Which one is going to make it a true statement?” So my hope is, hang in there because I think some of the meat of the unit is coming up in those activities.

In this example, the mathematics coach shared strategies to convey important ideas for an upcoming lesson. This type of discussion is characterized as “tips and tricks” (Horn et al., 2017) or “planning” (Graham & Ferriter, 2008). This type of plan team discussion centers attention on teaching rather than student learning while pedagogical concepts are not explicitly developed for teachers. This type of conversation can be characterized as monological (Graham & Ferriter, 2008; Horn et al., 2017). Overall, my observations of plan team meetings showed similarly low-level conversations. Teachers did not collaborate to review student work and did not provide opportunities to analyze instructional supports or concept development for future lessons. This was a missed opportunity because plan teams did not consistently support teachers in developing ambitious mathematics practices.

Observation and Co-Teaching Feedback

Mathematics leaders also supported the development of mathematics teachers through observation and co-teaching feedback. Cam primarily observed teachers’ classrooms while the mathematics department chair co-taught lessons with them. Cam observed teachers but tended to spend more time with early career teachers or those new to the school. Her classroom visits were typically unannounced unless the teacher asked for an observation. Jesse co-taught with most of the mathematics teachers at least once

during the school year. Both mathematics leaders felt that it was helpful to support teachers without being in an evaluative position and to provide support as a peer. I discuss the types of feedback given by the mathematics leaders in this section.

In contrast to administrators, mathematics leaders provided mathematically specific feedback 60% of the time (See Table 4.1). They also provided more suggestions for teachers and made fewer appraisals (36% and 44% respectively) with almost three-quarters of the suggestions being mathematically specific. Similar to administrators, mathematics leaders also supported teachers with structures to support groupwork and engagement but did not discuss culture and climate as frequently as administrators. Observation and interview data showed that feedback and coaching focused predominantly on the math content and delivery.

One area of mathematically specific feedback addressed “supporting productive struggle in learning mathematics” (Leinwand et al., 2014). For example, Cam noticed in one observation with Shay that the students all set up a proportion in the same way, based on how the teacher drew the example on the board. She provided feedback to the teacher about setting up the problem so that students could approach it in different ways. Cam asked questions to guide Shay’s thinking: “If you set up the problem differently, what other strategies do you think students would have used?” Through questions like these, Cam supported the teacher to use tasks with multiple solution paths and to elicit them from students. After a different observation, Cam provided another teacher with strategies to support productive struggle by suggesting the teacher give students private think time so that they would have access to the problem, and make sure that students

were using each other as resources. In both of these examples, Cam provided concrete strategies to support ambitious mathematics practices within teachers' classrooms.

The most common area of mathematically specific feedback addressed “facilitating meaningful mathematical discourse” (Leinwand et al., 2014). Cam gave Taylor the following suggestion from her observation looking at variations in students' answers:

In first period, 301 and 48 years seemed to be common because there is actually a couple of others before that got 48... “So I need you guys to analyze for me the people that got 48. What happened?” Because analyzing errors is just as important as getting there.

In this case, Cam encouraged Taylor to provide opportunities for students to discuss and analyze approaches to the problem; specifically what led to an incorrect answer? Cam also supported teachers in developing “posing purposeful questions” and “implementing tasks that promote reasoning and problem solving.” These kinds of conversations were dialogic in nature and provided a high level math press to support teacher learning (Horn et al., 2017; Rigby et al., 2017). Overall, the mathematics leaders were able to provide feedback to teachers that supported different facets of ambitious mathematics practices through observations and co-teaching feedback.

Mathematics Teachers' Views of Mathematics Leader Support

Mathematics teachers' views of support were impacted by the division in the department. In regard to plan teams, both in-group and out-group teachers liked the idea of plan teams and having the time to work with colleagues. In-group teacher, Blair, discussed being able to learn from colleagues, asking questions, and bouncing ideas off

of one another during plan teams. However, while teachers said that they liked plan teams, out-group teachers expressed some frustrations, including feeling that their needs were not met and their ideas were not valued. They also discussed the limitations of instructional conversations during plan team meetings. Riley felt anxiety when planning and teaching lessons, even after meeting with his plan team, because he did not always know how the lessons were going to play out. Jordan felt criticism in her plan team when she tried to adjust her instruction in her classroom:

I like the curriculum but at the same time, I feel like I know what's best for my specific kids and if I need to veer in a different direction or give additional assignments or choose a different assignment, I should have the ability to do that without feeling guilty and without being criticized for doing it. I taught a number of years that I know the standards, I know it is expected and when I try to teach fill in those gaps, I get my hand slapped for it. So that's my struggle with kind of what's going on. But my evaluator even says: "you just walk back into your classroom and do what's best for your kids and I support you."

As this example demonstrates, some teachers did not feel that they were allowed to use resources outside of the curriculum to meet their students' needs. Out-group teachers wanted plan team meetings to better meet their needs and to bring ideas without judgement. In-group teachers felt that plan teams were positive and productive.

In-group teachers felt that the mathematics coach's and department chair's feedback was helpful in improving their practice. For example, Blair explained how valuable the feedback was in helping her to be reflective and think about her instruction. However, out-group teachers felt differently. Shay acknowledged that the mathematics

leaders were more supportive of teachers who were aligned with the department's philosophical views of the curriculum. Jordan felt the need to defend her instructional choices instead of receiving feedback to improve. Taylor also felt that the feedback received from mathematics leaders reflected an attitude of "my way or the highway" and was less likely to consider implementing the feedback into her classroom. Instead of shifting their feedback delivery or reflecting on these statements, mathematics leaders said that feelings of judgement were an excuse for teachers not wanting to do the work. They also complained that it was hard to give feedback because teachers were sensitive about their practice. The lack of in-depth conversations during plan teams and feelings of judgement hindered the development of ambitious mathematics practices.

Summary

In conclusion, there were missed opportunities around both plan teams and observations. Plan teams showed low levels of conversation and centered around aligning instruction rather than deepening pedagogical concepts. In my own personal experiences and the plan teams I observed, much of the time was spent talking about previous lessons and pacing. Observation feedback from mathematics leaders was more mathematically specific than administrators' feedback and supported the development of ambitious mathematics practices. However, out-group teachers did not see feedback as helpful and instead felt judged. Mathematics leaders put blame back on the teachers, hindering the development of ambitious mathematics practices.

Administrator/Mathematics Leader Relationships

It was that part of the interview where I am sitting in a little office and I don't quite know whether this is on or off the record. I have started recording (so I don't

forget) but I haven't asked any questions. This participant has something they want to get off their chest before I start to ask my questions. They open their mouth and the tone gives me pause. My weird position of being a teacher in the school as well as a researcher makes me tense, because this is not a typical conversation that a teacher would have with a school leader. I listen intently, nod, and try to be understanding of their viewpoint. Honestly, the understanding isn't the difficult part—I get it, I get both sides. I agree with both sides. I disagree with both sides.

I try to bite my tongue as best I can, but I have opinions too, both as a teacher and as a researcher. As a teacher, I want to share my thoughts to disagree and sympathize with what I am hearing. As a researcher, I know the best thing for me is to be neutral and keep my opinions to myself. What I have read, what I have studied, what I have researched swirls in my mind wanting to come out. But I just keep smiling and nodding, holding it all in. Finally, the moment passes, the gossip part of the interview is over but now I have new information to protect. This responsibility adds new weight; I want to run and tell a co-worker, somebody. But I can't. I have to keep it as I go teach a class. Later I'll write it all down.

As I write down my experience, what I heard, what I can't share and what I can share, I wonder what truth it holds. I haven't been able to see this interaction my colleague is referring to in person, so I have no way to experience it myself. I have contradictory opinions and I try to reconcile participant views as I think about how this will play out as I write about it (Fieldnotes, February 22, 2019)

The interviews I conducted were often contentious, and I was placed in a position that my teacher colleagues are rarely in—one of a listener with an inside view of the

politics and contentious relationships within the school. This was something I had to learn to navigate in my dual role as a teacher and a researcher. These insider conversations and interviews happened frequently when discussing the relationship between administrators and mathematics leaders. As a teacher, it was not appropriate for me to attend meetings between the mathematics leaders and administrators and so I relied on participants' perspectives on this relationship during their interviews. Because mathematics leaders were a part of the in-group and administrators were a part of the out-group, distrust and a lack of communication were evident.

Feelings of Distrust

Mathematics leaders' perceptions of administrators' support fostered a level of distrust. For example, mathematics leaders felt supported from administration with regard to the structures of the mathematics department, particularly around plan teams and the curriculum. They were given the freedom to make choices that they believed supported students in learning mathematics. However, the department chair, Jesse, also showed hesitation about the support they received from administrators:

I think [administration wants to be supportive]; they just get really nervous around the work we do. But I think they truly want to be. They get a lot of the parent pushback. I worry that they don't really understand what a student-centered classroom looks like. I worry that they don't understand student ownership of learning. So it's tough to get feedback from them on those things because I'm not sure they're quite comfortable with what that really means... [the principal] believes we're doing the right work.

Here, Jesse argues that administrators do not understand the goals of the department but wanted to be supportive. In contrast to Jesse's view, Cam felt that administrators constantly criticized the work that the mathematics leaders were doing and felt more distrust with administrators. In particular, she felt that communication with Alex, the principal, was negative.

From the administrators' perspective, they felt that they were supportive of department goals and had a good understanding of the curriculum and instructional practices but still felt a level of distrust from mathematics leaders. Andy explained this distrust he felt from the mathematics leaders:

I think there is a blatant distrust of administration... [But] I'm continually amazed by how well almost every one of our administrators can speak about our math [department] and I don't know if that's known or not but the reason for the discontent, I don't want to dismiss that because I think every school has that but it seems from people not feeling understood or appreciated.

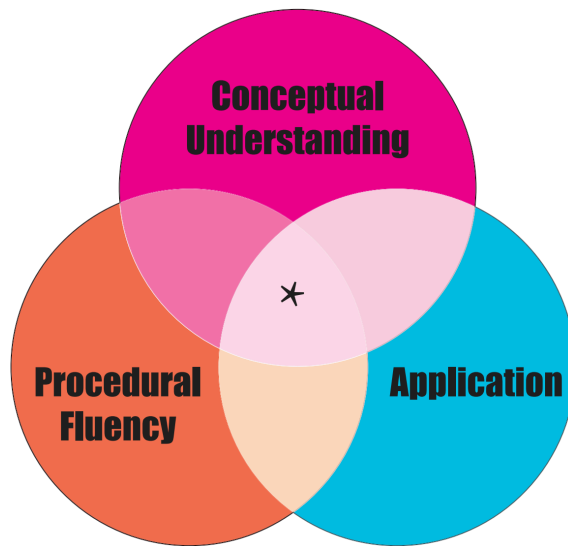
Andy acknowledged this distrust but did not quite understand why it existed. He saw administrators work to understand and support the mathematics department but acknowledged that mathematics leaders may not see that work happening inside the administrative offices.

One example that illustrates this distrust between administrators and mathematics leaders emerged with the principal (Alex) and the mathematics department chair (Cam) discussed the idea of procedural fluency. Cam thought that they disagreed on what procedural fluency looked like in the classroom. Throughout the year, Alex advocated for mathematics instruction based on a Venn Diagram consisting of three circles representing

conceptual understanding, procedural fluency, and application where the best instruction fell within the center of the three (See Figure 4.1). Alex frequently referenced this diagram in meetings and pre/post observation conferences with mathematics teachers; however, it was not shared with the entire department in an intentional way.

Figure 4.1

Mathematics Instruction Venn Diagram



Alex often illustrated his idea of procedural fluency using the metaphor of his woodworking hobby:

I liken it to my wood shop and my power tools. If you only use one tool every once in a while, you develop no procedural fluency and then you have to take out the book again and remind yourself how to do it. And so I think that the tools you're using most frequently or with a great level of fluency, you have better access to and more regular access to. So I think there needs to be enough repetition to build that procedural fluency. And then one of the sticking points that I think we face when it comes to application: are we developing enough of the

disciplinary literacy that once students step away from a particular curriculum resource, can we utilize that foundation we've built in the conceptual understanding and in the procedural fluency to address questions that may not appear in the same type of context in which they learned the math?

Cam described her interpretation of the principal's goal of procedural fluency as being synonymous with memorization:

I think a common belief is that we're not attending to the procedural fluency. My response to that is not that I don't think it's important, it's just we have to differentiate for kids... I think procedural fluency somehow gets discombobulated with the word memorize and regurgitate which is actually the antithesis of what we want.... [we want them to] have something to leverage when their memory fails.

Cam believed that procedural fluency could lead to a focus on memorization and she appeared to be worried about that happening within the department. However, Alex's understanding extended beyond memorization to ensuring that students could access their learning in a variety of different contexts and settings. It seems that both Alex and Cam were on the same page; however, Cam assumes that Alex wants to take the focus away from ambitious mathematics practices. Because Cam and Jesse felt that administrators did not understand the goals of ambitious mathematics practices, they show a level of distrust of administrators. From my perspective as both a teacher and researcher, both administrators and mathematics leaders had similar goals for the mathematics department however, mathematics leaders struggled to see these common goals. It was frustrating to see mathematics leaders continue to deny these commonalities.

Lack of Communication

Feelings of distrust led to a lack of communication. Both groups frequently discussed their lack of meetings. For example, the department chair, Jesse, was the primary communicator with the administrators about supporting teachers but felt that she did not work with administrators as often as she would have liked. Jesse tried to “stay out of [administrators’] hair”. Cam recalled meeting more frequently with past principals to discuss instruction and mathematics department goals but did not meet frequently with current administrators. Blair even discouraged Cam and Jesse to meet with administrators because many past meetings felt negative when they were questioned about the curriculum or poor SAT scores.

The administrators also felt that they did not work well with mathematics leaders. All three commented that there were not many opportunities to collaboratively support instruction. Andy, who was also in the role of mathematics department liaison, felt that the mathematics leaders used him more as clerical support but wanted to have more substantive conversations around mathematics:

I wish I was able to have more conversations with [Jesse] about actual math instruction that's going on... In a couple of years, we have not gone into a teacher's classroom together nor have I been asked to share any type of observation notes or thoughts about a certain teacher. I will oftentimes do that myself. I feel like my relationship with [Cam] is nonexistent when it comes to supporting teachers.

Andy wanted to collaborate and have instructional conversations but did not have those opportunities with either mathematics leader. He also acknowledges the benefits that would result from observing classroom instruction together or discussion observation

notes about a certain teacher. These activities would support the development of ambitious mathematics practices within the school and would be beneficial for teachers, administrators, and mathematics leaders.

The lack of communication did have an impact support for teachers. Jamie acknowledged that the administrators and mathematics leaders were not always coaching the teachers in a similar way:

When I talk informally with the department chair or math coach, we may differ on what we think is good instruction. So that is part of my learning curve with math is because what you guys think is good instruction and what I feel like is good instruction in general, maybe we're off a little bit. So maybe we're coaching that teacher just a little bit differently. So that is that's probably my biggest challenge and I'd say, "Hey, take this chance" and maybe the math coach says, "Stick with the company line here, this is what we do."

This comment shows that while administrators and mathematics leaders have similar goals and views of mathematics instruction, they may not be on the same page when it comes to giving feedback to teachers to support ambitious mathematics practices.

Conversations around mathematics were expected to be directed to Cam, the mathematics coach, instead of collaborating to provide feedback to teachers.

In another example, Andy stated he was more likely to consult with Jesse about how mathematics teachers were progressing, rather than Jesse seeking out Andy. Andy did not seem to agree on the approach to supporting teachers that mathematics leaders sometimes had:

With Jesse, I tend to seek her out more often... And sometimes that results in a tough conversations where I realize that in this particular instance, she's kind of written this [teacher] off. This person is going to be a one year and out of here type thing or isn't really fitting in. And I'm like, "I might be seeing it differently, if you guys back off in some of your rigidity, this teacher can actually really be supported." We find out that we're doing, saying different things and we have to get on the same page.

Andy highlights that mathematics leaders and administrators were not always on the same page when it came to supporting struggling teachers. Mathematics leaders were quick to write these teachers off where Andy wanted to provide more support. With a lack of communication between the two role groups, it is unlikely that administrators and mathematics leaders would be on the same page with supporting teachers.

Summary

The administrators' and mathematics leaders' division along in-group and the out-group lines led to distrust and a lack of communication between the two role groups. Because I did not observe any of these first hand, I had to rely on interview data. Interviews were often filled with a level of frustration when discussing the other role group before, during, and after, as I describe above. Although mathematics leaders acknowledged the support they received from administrators, they still did not feel that they were on the same page with regards to mathematics instruction, this led to feelings of distrust. Distrust also led to a lack of communication between the two role groups which impacted the support teachers received. This is another missed opportunity for supporting the development of ambitious mathematics practices with teachers.

Administrators and mathematics leaders should collaborate regularly to support teachers. Administrators can support coaches in navigating interactions with teachers, create a coherent strategy that supports system-wide instructional change in mathematics, and develop a strong relationship with the mathematics department (Hopkins et al., 2017; Knapp, 2017). This collaboration would support administrators to better understand and provide mathematically specific feedback and would give more opportunities for teachers to be successful.

Intersection of the Relationships

I walk into the PLC meeting with my computer and a lunch fresh out of the microwave that is burning my hand. I am laughing with a co-worker as I find a seat around the circle of desks—we usually sit in table groups. The vibe in the room feels slightly ominous; three administrators are sitting in the circle, and I forgot to read the agenda to see what today’s PLC meeting was about. I wait quietly while the rest of the mathematics teachers trickle in, while the smells of different microwaved leftovers fill the room. I open my computer to take a few notes, it seems like the meeting may be important. Packets of paper are passed around with different pieces of data: SAT scores, Accuplacer scores, AP scores, etc. I look through the papers quietly.

The conversation starts with a discussion about concurrent enrollment classes where students receive college credit toward an associate degree that can also transfer to colleges and universities. The administrators are looking to offer four different concurrent enrollment classes next year based on student interest. It seems straightforward, but the tension in the room continues to grow between the administrators and mathematics leaders when the statement is made that students will no longer be able to

take the concurrent enrollment College Algebra course without passing the Accuplacer test. The mathematics leaders and a few teachers show defensiveness when the underlying reason for this change is that the IMP curriculum doesn't follow the traditional course sequence. "Someone is too lazy to do the alignment work," Cam argues. Their frustration is coming out on the administrators in the room when they are simply communicating a decision they had no control over. A contentious discussion starts about these tests not measuring the outcomes of IMP. I catch a glimpse into the commitment these mathematics leaders and teachers have to IMP curriculum. However, most teachers sit in silence watching the conversation unfold. Some are uncomfortably eating their lunch, quietly checking email until the meeting ends, when teachers return to their classrooms. I wonder if they are having the same thoughts I am having.

It is November and I know that I have felt this before; it is some sort of internal dissonance that I am having trouble reconciling each time I have conversations with Cam and Jesse. This time, I am able to articulate it a little bit better. I am feeling conflicted about the position that if I support ambitious mathematics practices, I had to be against test scores. While I researched the high school's performance before, for the first time I am realizing that wow, test scores are low and scores are lowest in the district. I struggle with this question: if we are focusing on ambitious mathematics practices, if we are teaching the right way, shouldn't our test scores be higher? (Fieldnotes, November 16, 2019).

This particular PLC meeting became a focus of many of my subsequent interviews. This meeting revealed the differences in opinion and the tension between mathematics teachers, mathematics leaders, and administrators. While administrators

expressed their concern for test scores in the PLC meeting, mathematics leaders showed their resistance to these conversations. Furthermore, I felt mathematics leaders' strong hold on the IMP curriculum for the first time. This PLC meeting also revealed that only a few teachers within the department felt comfortable voicing their opinion while others sat in silence during the meeting. While the administrators, mathematics leaders, and mathematics teachers interacted with each other in different ways, they intersected around two areas: instruction, and test scores and graduation competencies. These factors impacted all facets of the interactions and relationships explored earlier. As a whole, all participants held similar views about these three areas but had differing opinions on the necessary steps to continue to improve as a department and school.

Instruction

Conversations about instruction took place primarily during plan team meetings since administrators relied on plan teams to provide instructional support for teachers. Administrators assumed that because of the collaboration with the mathematics department and the IMP curriculum, they did not have to spend as much time providing feedback and supporting math teachers on lesson planning and instruction as they did with teachers from other departments. Alex discussed the benefits of observing mathematics teachers: “[conversations around] lesson design... doesn't happen as much in math because [the curriculum is] pretty mapped out for you guys.” Jamie explained how plan teams compensated for the limitations of their role in providing consistent feedback and support: “Math teachers get more from working with their plan teams and having those conversations every day, being able to share their frustrations with each other, and then get that weekly feedback. Whereas administrators, we don't give that consistent

feedback.” Based on interview data, it seems that mathematics leaders appreciated this control over the instructional support for teachers and preferred less intervention from administrators.

Administrators encouraged the use of plan teams to support teachers in solving problems. For example, in a post-observation conference, Jamie and Riley discussed how students often struggled when they were asked to generalize (such as creating an equation that modeled a situation). Jamie suggested addressing those struggles during plan team meetings:

To me that seems like what planning team conversation should be about. It's like, “Okay, we're doing this unit... but here's what I feel like we're missing and we're not getting, and you guys thought the same way.” What can we do differently or add that would be a good use of your guys’ time in those [meetings]?

However, Riley acknowledged that he did not often have the opportunity to have these instructional conversations during plan team. Because plan teams consisted of low-level conversations, like tips and tricks for lessons and pacing, plan teams were not as effective in supporting instruction as administrators hoped or assumed.

When Andy evaluated veteran teachers, he often asked how they were sharing their instructional strategies with their plan teams. For example, Andy asked Jesse:

You put [students] through a pretty interesting protocol when you were developing the steps... I don't know if that's a common-sense approach or if that's something that you do all the time when it comes to stuff like this? I guess I'm wondering if your colleagues, if [your plan team], if they're doing the same technique or if that's just [your] thing?

Jesse reflected on this question, but did not acknowledge or respond to it; I do not know if she actually discussed this strategy with her plan team. Administrators hoped that plan teams were beneficial for teachers to share ideas about the curriculum and planning lessons to meet students' needs, but this did not occur consistently. Overall, administrators assumed that because conversations about instruction happened in plan teams, lesson planning conversations during the evaluation process were not needed.

Test Scores and Graduation Competencies

Mathematics leaders felt that test scores and graduation competencies overshadowed the department's work with the curriculum and instructional practices. Jesse commented on the pressure they felt from administration:

[Administration is] so consumed with test scores and graduation competencies that they forget about the great stuff we do. A comment was made to me, "We're nine out of nine in test scores" ... And I get test scores are concerning and I believe it doesn't mean that we should ignore them. But it felt like this year more than ever, there was some sort of filter, that there was a lot less celebrating what we do and a lot less acknowledging that we're doing a lot of good work. So as the [department chair], I'm trying to continually encourage them to see that. It has been challenging this year to say the least. It's hard to walk the line between accountability and doing right by kids and to fight for what we do.

Jesse claimed that support from administrators waivered because the school had the lowest test scores in the district. Cam also felt that the administration was supportive of the mathematics department's goals until test scores were low. Both mathematics leaders

felt pressure from administrators around test scores and graduation competencies and felt less supported with the department's goals and the IMP curriculum.

Cam and the administrators both acknowledged that the SAT was not the best measure of students' learning nor did it reflect the goals of the department. Andy acknowledged this fact but still advocated that data could be used to improve instruction:

I think [the mathematics leaders] see any type of focus on SAT as an invalid tool and I have two thoughts on that. One is in some respects [the SAT is an invalid tool] but it's real and there's data that comes from it and we can be informed by that data. How can we address [those gaps]? ... It's an existential conversation for some folks. They feel like if they would have the conversation about SAT scores in math, it's going to be basically saying goodbye IMP and that's important to realize, it's very emotional.

Jamie made a similar comment that the leaders in the mathematics department were protective of their philosophy of teaching and were not always open to looking at test scores. Mathematics leaders felt that focusing on test scores would then lead to a focus on memorization and more traditional teaching practices, which they had experienced at other schools. It is a common pattern when schools focus on increasing test scores (Day, 2004; Garner et al., 2018; Schoenfeld, 2002; Sharpe et al, 2018).

Administrators noticed the lack of classroom freedom that mathematics teachers experienced and made similar comments. For example, Jamie was concerned that mathematics teachers were not differentiating enough:

My concern is that we recognize [students are] low-performing or they're struggling but our approach sometimes is, "Well, they just need to try it again" or

to stay in the same model—a one size fits all... We want teachers to differentiate. We probably don't do enough because we're married to our curriculum and we're all planning together and working at about the same pace in all of our classes. We don't feel the freedom in our building to differentiate as much as probably we should... I do think that we're a little bit handcuffed by some of our belief system. Here, Jamie advocated for more responsive instruction and conversations around ways to better meet students' needs and struggles. Andy made similar comments:

I think what hurts the most is, let's talk about [instruction] and if that means we need to insert a page one and a half in our textbook from page one to two or we need to take out page three, okay. But when the message is no, because you'll ruin [the curriculum], what are you saying to your teachers? You're saying, "I don't trust you; you don't know what you're doing" ... that's [the message they're sending].

In both of these comments, the administrators realized that teachers were not able to differentiate for their students by adjusting the curriculum but agreed that it was an important conversation. They understood the dynamics in the department where in-group members did not trust teachers to change the curriculum. Making changes to the curriculum, like the example of the "Tri-Square Rug Game" activity was seen by the in-group as "ruining" the curriculum.

The alignment and fidelity to the curriculum impacted discussions around improving instruction and using assessments as a tool to measure its effectiveness. Andy described a conversation with a district curriculum, instruction, and assessment specialist: "But instruction really matters. Yes, those are the standards that are meant to be covered

[but] we need to talk about the instruction and how you're assessing that instruction before we can just go, 'Oh we [teach] that.'" Andy also felt that many teachers expressed fear to share their ideas with the department. From the administrator perspective, mathematics leaders assumed following the curriculum was equivalent to meeting the standards and there was little opportunity to discuss instruction or examine student data. Ultimately, both administrators and some teachers saw the need for more freedom to share ideas within the department and more conversations about instruction and assessment.

Summary

Interactions between all three role groups converged around instruction, test scores, and graduation competencies. There were several problematic aspects. First, administrators assumed that conversations around instruction were happening in plan teams and they did not have to support mathematics teachers in this area as much as other subjects. However, there were two examples where conversations around instruction were not happening in plan teams as in depth as they could have been. And as we saw before, plan team conversations focused mostly on logistics, tips and tricks, and big ideas. Another problematic aspect was the resistance to examining SAT data or using assessment data in general and create a plan for and measure the effectiveness of instruction. These conversations always sparked frustration and controversy between the in-group and the out-group participants. Conversations around instruction, test scores, or graduation competencies never moved forward and never resulted in any solutions or next steps. Several participants noted that teachers felt handcuffed by the curriculum or the belief system that did not allow them to differentiate for students. Administrators saw

that teachers did not have the freedom to effectively differentiate for their students without being seen as “ruining” the curriculum.

Conclusion

In this chapter, I presented the major themes from over 40 interviews and observations of mathematics teachers, mathematics leaders, and administrators.

Administrators, mathematics leaders, and mathematics teachers articulated similar goals for the mathematics department. Despite this alignment, the division between two groups of teachers in the department impacted the relationships between the three role groups and support for ambitious mathematics practices. Out-group members viewed in-group members as judgmental and resistant to discussing instruction and test scores. Out-group teachers were more likely to respond to feedback from administrators rather than mathematics leaders and were critical of plan teams. The in-group and out-group division also impacted the relationship between administrators and mathematics leaders, leading to distrust and a lack of communication. In the final chapter, I discuss these findings in the context of the research questions.

CHAPTER 5: DISCUSSION

Previous research on supporting ambitious mathematics practices has focused on isolated relationships between administrators, mathematics teachers, and mathematics leaders. This is a gap in the literature because instructional improvement has not been examined through a coherent instructional system. This study's examination of the relationships between administrators, mathematics teachers, and mathematics leaders revealed how the activities of the three groups of participants were intertwined within communities of practice (Cobb et al., 2003; Wenger, 1998).

The purpose of this case study was to examine how ambitious mathematics practices are supported and sustained within a high school facing pressures to increase test scores and meet graduation competencies and to see how the roles and responsibilities of school leaders support that change. To address this issue, my primary research question stated: How do the relationships between administrators, mathematics leaders, and mathematics teachers at a large, suburban public high school support ambitious mathematics practices? Sub-questions for my study include:

- How do internal and external factors influence administrators and mathematics leaders' support of ambitious mathematics practices with mathematics teachers?

- How do administrators and mathematics leaders provide content-specific coaching to mathematics teachers to support ambitious mathematics practices?
- How do administrators collaborate with mathematics leaders to support ambitious mathematics practices?
- How do mathematics teachers perceive administrators' and mathematics leaders' support of ambitious mathematics practices?

To answer these questions, I used a single case study design and chose a high school that has implemented ambitious mathematics practices for the past several years. I collected data through interviews, observations, and artifacts to describe and interpret the interactions between the three role groups in both formal and informal settings. I analyzed the data using first and second cycle data coding to create a naturalistic generalization (Creswell, 2013).

Summary of Findings

Prior research on coaching and evaluating mathematics teachers has examined isolated relationships between administrators and mathematics teachers, mathematics leaders and mathematics teachers, and administrators and mathematics leaders. This created a gap in looking at how ambitious mathematics practices are supported through a coherent system. Cobb and Jackson (2011) argue for a theory of action for instructional improvement in mathematics that stresses the need for teacher learning as well as organizational learning. Instruction is intertwined within different communities of practice; and therefore common goals and a coherent system of supports are needed to promote instructional improvement (Cobb et al., 2003; Cobb et al., 2018). Below I

summarize the study findings to answer my four research sub-questions followed by my primary research question. While there were several positive examples of how ambitious mathematics practices were supported, ultimately disagreements in regard to curriculum and test scores between administrators, mathematics leaders, and mathematics teachers affected the support for these practices. These disagreements would not have been revealed without examining all three relationships.

Sub-Question #1: Internal and External Factors

The participants in this study held unusually positive views of students' mathematical capabilities (Jackson et al., 2017) and strong visions of high-quality mathematics instruction (Munter, 2014) compared to previous research. These positive internal factors — beliefs and backgrounds, including leadership content knowledge — contributed to participants' alignment to ambitious mathematics practices. It was important to note that these strong beliefs about mathematics instruction were consistent among participants and is something that is uncommon in many schools (Garner & Horn, 2018). I will start this section by discussing the external factors that supported the development of strong views of mathematics instruction. After, I will reveal instances of internal factors not in alignment with ambitious mathematics practices.

External factors include tools and social interactions (Eun, 2008). The predominant external factor contributing to the development of beliefs and views of mathematics instruction was the communities of practice at the high school. The mathematics department could be considered a network of communities of practice in which mutual engagement is sustained in a social and historical context toward a shared goal (Wenger, 1998). Wenger argues that sustained engagement and negotiation of

meaning in the community of practice creates personal histories and develops the identities of its participants. Many schools do not have time during the school day for sustained collaboration and lack coaches or leaders to facilitate teams (Horn et al., 2018). Teachers in this study benefitted from and expanded their vision of ambitious mathematics practices through this community of practice.

Previous research shows that administrators have the ability to increase their leadership content knowledge and improve their own knowledge of mathematics through learning about effective practices (including professional development), observing mathematics classes taught by experienced teachers, and interacting with mathematics leaders (Burch & Spillane, 2003; Nelson, 2010; Rigby et al., 2017). In particular, interactions with mathematics teachers have the potential to impact administrators' views of mathematics instruction. For administrators in this study, the most impactful external factor was the academy model where teachers were divided into interdisciplinary teams, rather than by department. In contrast to high schools with isolated departments, the academy model allowed these administrators to have more interactions with mathematics teachers, increasing their leadership content knowledge in mathematics. As a result, administrators were advocates for the IMP curriculum and prioritized the structures of the mathematics department, for example, creating the schedule to accommodate plan teams.

This study also revealed internal factors not aligned with ambitious mathematics practices. For mathematics leaders, previous research assumed that they had the necessary beliefs and backgrounds for their roles and rarely discussed their alignment to ambitious mathematics practices. In this research study, mathematics leaders, Cam and Jesse, held strong views of mathematics instruction, showing high scores on the VHQM

(Munter, 2014) and VSMC (Jackson et al., 2017) protocols. However, mathematics leaders also showed weak leadership content knowledge by pushing fidelity to the IMP curriculum as the best way achieve ambitious mathematics practices. They were resistant to conversations that strayed from the curriculum, including those about outside resources and test scores. Furthermore, the attachment to the curriculum created division in the department leading to an in-group and an out-group that was rooted in the debate about the curriculum.

This in-group and out-group division was a consistent theme throughout the study and persisted even though there was strong philosophical alignment between study participants. Wenger (1998) argues that communities of practice are not always unifying, but instead can be divisive. In both interviews and observations, in-group participants tended to focus more on their differences in approach to instruction, rather than similarities in their beliefs, common goals, and visions about instruction. In-group members feared that changing or losing the IMP curriculum would result in an abandonment of ambitious mathematics practices within the department. Additionally, in-group members thought that deviations from the curriculum were an attempt to reduce the cognitive demand of the mathematics. This led out-group members to feel judged since they shared the same beliefs about mathematics instruction but did not believe in strict fidelity to the curriculum.

Within a community of practice, ownership is the result of shared responsibility for the negotiation of meaning (Wenger, 1998). When some members of a community of practice are left to consistently adopt the ideas of others, certain members are marginalized and have a decreased ability for learning. This alignment created power

relationships within the department and while compliance was efficient, it also limited the ability of the community to adapt to new situations (Wenger, 1998). In-group teachers' charge to "trust the curriculum" was a call for fidelity. Santoro (2016) argues that the word "fidelity" is used to manipulate teachers and keep them in line. However, teacher resistance to fidelity is an attempt to use pedagogical responsibility and thoughtful response to the demands of the classroom. Teachers who resist are not involved in insubordination, but rather engaging in the moral work of critically examining the connection between the ends and means of education (Dewey, 1916; Santoro, 2016).

Out-group members questioned the curriculum as the sole curricular resource. The belief that the textbook defines what is important to include or exclude as the curriculum is unproductive — meaning it does not support effective teaching and learning and limits student access to mathematical practices and content (Leinwand et al., 2014). It was also unproductive to believe that a curriculum would not benefit from evolving and adapting to the needs of the school and students (Doerr et al., 2010; Leinwand et al., 2014). Social and material resources, like a curriculum, are the foundation of ambitious teaching, but teachers should adapt these resources to be responsive to students' needs (Lampert et al., 2017). Furthermore, no single representation, like using the "Tri-Square Rug Game" for teaching Pythagorean Theorem, can be seen as equally beneficial for all students. Good teachers must analyze and select representations that are both responsive and responsible for their students (Ball, 1993). Teachers need a variety of alternative models to draw upon and a variety of resources to support the instructional decision-making (Ball, 1993; Lampert et al., 2017). Out-group

teachers pushed against the curriculum as the sole resource in order to be responsive to their students' needs. Administrators also recognized that being "handcuffed" to the curriculum led to a lack of conversation around instruction. While the community of practice contributed to strong visions of mathematics instruction for administrators and shared goals for the department, internal and external factors also negatively impacted the support for ambitious mathematics practices for in-group members.

Sub-Question #2: Content-Specific Coaching for Mathematics Teachers

While mathematics leaders provided mathematically specific coaching a majority of the time and administrators some of the time, there were missed opportunities for improving ambitious mathematics practices that fell into three categories. These missed opportunities were seen in each facet of content-specific coaching: the evaluation cycle with administrators, coaching from mathematics leaders, and plan teams. The first missed opportunity was in the evaluation cycle. Administrators' feedback was consistent with prior research: influenced by their experience and content area expertise, was less mathematically specific, and focused on performance strengths more often than areas of improvement (Lochmiller, 2016; Mette et al., 2015, Sharpe et al., 2018). Administrators focused providing feedback on culture, norms, and expectations saying that it was an important to create a positive environment for students. Sharpe and colleagues (2018) agree that administrators have the responsibility of maintaining the safety of students and promoting the school's mission across content areas and it is not always reasonable to expect them to provide feedback on ambitious mathematics practices. However, administrators' focus on larger school goals does not have to take away from the goals of the department (Sharpe et al., 2018).

The administrators in this study were interested in spending more time in classrooms and were interested in having deeper conversations about mathematics instruction. Unfortunately, other responsibilities reduced the amount of time they had for classroom observations and working with teachers. Furthermore, in-group members — some of the most experienced mathematics teachers in the school — did not trust administrators to have deeper conversations about mathematics instruction. They used administrators as data collectors during the evaluation cycle and assigned them a specific task or look-for rather than recognizing the administrators' expertise. These teachers would then analyze their data separately, without the help of their evaluator. These stunted evaluation conversations and hindered the capacity of administrators to provide more mathematically specific feedback.

The second missed opportunity came with coaching mathematics teachers. Prior research has shown that mathematics leaders often have a variety of duties that diminish their focus on achieving instructional improvement goals (Campbell & Griffin, 2017; Chval et al., 2010; Mudzimiri et al., 2014; Zepeda & Kruskamp, 2007). In my study, however, the mathematics leaders spent most of their time working with teachers and students and had a clear role to play within the department. When engaged in coaching activities, mathematics leaders provided more mathematically specific feedback to teachers than administrators, over 60% of the time. This mathematically specific feedback supported the development of ambitious mathematics practices. Also consistent with prior research, pop-in observations were found to be the most common coaching activity aside from leading plan teams (Kane et al., 2018). Pop-in observations were a missed opportunity for coaching mathematics teachers at this high school. Research

shows that mathematics leaders should engage teachers in modeling, co-teaching, and completing coaching cycles. Pop-in observations are not necessarily productive and seemed like a check-up on how the curriculum was being implemented, or a “gotcha” in this case rather than an opportunity for teacher learning. The planning phase of a coaching cycle can help teachers understand the rationale for particular instructional practices and support the development of a shared discourse (Kane et al., 2018). Goal setting, collaboration, and focusing on student thinking are also critical aspects productive coaching activities and pop-in observations did not consistently meet those goals at this particular school (Gibbons & Cobb, 2012; Mudzimiri et al., 2017; Neuberger, 2012).

The third missed opportunity came from plan teams. While mathematics teachers at this school collaborated more often than many teachers across the country (MetLife Foundation, 2009), it was unlikely to support teachers’ opportunities to learn and deepen their practice. Plan team meetings are another important source of feedback for teachers when developing ambitious mathematics practices (Ellington et al., 2017; Knapp, 2017) but are less productive when focusing on pacing, logistics, or tips and tricks (Horn et al., 2017). Plan teams in this study worked at the level of “cooperating” and spent the majority of the time focused on tips and tricks and pacing (Graham & Ferriter, 2008; Horn et al., 2017). Teachers did not spend time reviewing student work, addressing challenges, or analyzing students’ learning (Horn et al., 2017). Furthermore, there was little collective interpretation connected to future work and teachers had few opportunities to engage in concept development or improve their instructional practices (Horn et al., 2017). Because out-group members’ deviations from the curriculum were

often met with “trust the curriculum” instead of engaging in conversations about best meeting students’ needs; it seems like conversations centered around collective interpretation connected to future work would help out-group teachers learn from the experiential knowledge of in-group teachers. Ultimately, plan teams brought down the depth of the conversations and the opportunities for teacher learning.

Consistent with Little’s (1990) appraisal of teacher collaboration, time spent collaborating can be inauthentic and outside of the real work of teaching. This is significant because many of the mathematics teacher participants in this study felt that there was little space for professional conversations about instruction that responded to students’ needs. When plan teams provide space to openly discuss problems of practice, they are more likely to maintain focus on instructional improvement (Horn et al., 2018). Potentially productive plan team routines for improving instruction include examining student work, analyzing student thinking, and planning intentional responses; rehearsing structures like launches to activities; anticipating places of student struggle in lessons; solving rigorous tasks together and discussing potential student strategies; analyzing classroom videos; and participating in a lesson study (Horn et al., 2018; Jackson et al., 2017; Schoenfeld, 2002). Ultimately, mathematically specific feedback is not enough to support ambitious mathematics practices; it is also important to provide teachers with opportunities to meaningfully collaborate and reflect on their teaching.

Sub-Question #3: Administrators Working with Mathematics Leaders

The mathematics coach and department chair worked together to support mathematics teachers, largely without the intervention of administrators. Even though administrators consistently showed alignment with the goals of the department, the

mathematics leaders felt that communication with administrators was negative and often avoided interaction altogether. This led to distrust and inconsistent instructional leadership. Prior research highlights the ambiguity mathematics leaders often feel within their role (Chval et al., 2010; Hartman, 2013; Knapp, 2017; Zepeda & Kruskamp, 2007). In my study, mathematics leaders did not express feelings of ambiguity since they mostly kept within the department and had little interaction with administrators. However, consistent with prior research, the lack of collaboration between mathematics leaders and administrators led to misalignments between the two role groups, and ultimately, inconsistent effectiveness in mathematics leadership (Hopkins et al., 2017; Knapp, 2017; Mangin, 2007).

Discussions about test scores were the biggest source of distrust between administrators and mathematics leaders. Administrators wanted to have more conversations about mathematics instruction, but mathematics leaders regarded administrators' focus on test scores as ignoring the positive work that the mathematics department was doing. Sharpe and colleagues (2018) argue that school leaders who are concerned with test scores often examine student data without considering the instructional reasons for low performance. This often leads to improvement efforts that ignore long term instructional goals (Sharpe et al., 2018). Mathematics leaders in this study feared this very thing — where administrators would focus on instructional strategies that promoted memorization and teaching to the test. However, there was no evidence that administrators would actually distort instruction at the school or had the goal to do so. However, mathematics leaders still avoided conversations with administrators. The lack of collaboration also led to inconsistencies in feedback given to

mathematics teachers where both role groups did not always provide consistent support for teachers. This hindered support for instructional improvement and support for ambitious mathematics practices.

Sharp and colleagues (2018) advocate for mathematics leaders and administrators to play equally important and complementary roles within a school to support ambitious mathematics practices; however, administrators have the authority to communicate instructional expectations consistent with district goals for improvement (Sharpe et al., 2018). Since administrators have the authority in the school to set instructional goals, mathematics leaders should work with administrators to embrace these expectations and create goals at the department level aligned to these expectations to better support ambitious mathematics practices while meeting larger district and school goals. Moreover, instructional goals and expectations from administrators or the district level and goals at the department level do not have to be in conflict with one another.

Sub-Question #4: Mathematics Teachers' Perceptions of Support

Mathematics teachers discussed their perceptions of support in regard to the feedback they received from both mathematics leaders and administrators, but also with the division in the department and their perceptions of plan teams. In-group and out-group participants differed in their views about feedback from administrators and mathematics leaders. Out-group teachers trusted and felt more supported by administrators while in-group teachers felt more supported by mathematics leaders. Because Shay was not firmly in either the in-group or out-group, he felt supported by both roles. In previous research, administrators' understanding of mathematics content was important to teachers when providing feedback on instruction and administrators

were seen as effective when teachers had the space to self-reflect about their instruction (Lochmiller, 2016; Mette et al., 2015). In this study, most mathematics teachers acknowledged that administrators did not always give mathematically specific feedback. They instead focused more on general instructional practices. However, out-group teachers argued that their general feedback supported the goals of ambitious mathematics practices.

Teachers felt that mathematics leaders were able to provide more mathematically specific feedback, but felt less support and more judgement when their philosophical views did not align with those of the mathematics leaders. The importance of mathematics leaders developing trust with teachers was a pervasive theme in previous research. Mathematics leaders developed trust through valuing authentic conversations, giving space for teachers to ask questions about their classroom instruction, developing personal relationships, and treating them as professionals and experts (Hartman, 2013; Mudzimiri et al., 2013; Knapp, 2017; Neuberger, 2012; and Zepeda & Kruskamp, 2007). Instead of working to develop teachers' trust, mathematics leaders blamed teachers for unwillingness to put in the work of the curriculum and lowering the cognitive demand of curriculum tasks. This ultimately caused out-group teachers to feel unsupported by mathematics leaders.

While it is important to have agreement in supporting ambitious mathematics practices, it is also important that experiences and competencies of participants are not marginalized by ignoring, fearing, and repressing their pasts (Wenger, 1998). Out-group teachers did not feel supported by plan teams. They commented that lessons in the classroom were still unpredictable after plan team meetings, they did not always know

how to address students' struggles and felt judged when trying to adapt lessons to meet their students' needs. Because plan team meetings typically focused on low-depth conversations, the institutional knowledge held by in-group teachers did not surface. Through this lens, plan teams did not consistently support the development of ambitious mathematics practices. Incorporating members' pasts into a community's history increases identities of participation (Wenger, 1998). Widening mutual engagement in practice can increase ownership of meaning for participants in the community of practice.

How did School Leaders Support Ambitious Mathematics Practices?

Communities of practice evolve within larger social and institutional contexts; they can evolve through submission or they can adapt social and institutional contexts to current practice (Wenger, 1998). Therefore, coherence can be both a strength and a weakness. Communities can maintain current conditions or redirect practice by fostering or avoiding relationships and artifacts to focus the negotiation of meaning. Wenger states that maintaining stability requires as much work as does transformation:

In the process of sustaining a practice, we become invested in what we do as well as in each other and our shared history. Our identities become anchored in each other and what we do together. As a result, it is not easy to become a radically new person in the same community of practice. Conversely, it is not easy to transform oneself without the support of a community... Communities of practice are also invested in reification. Tools, representational artifacts, concepts, and terms all reflect specific perspectives they tend to reproduce. Because of this investment of practice, artifacts tend to perpetuate the repertoires of practices beyond the circumstances that shaped them in the first place (Wenger, 1998, pg. 89).

The in-group's past experiences with the IMP curriculum shaped the visions, goals, and interactions within the mathematics department. As the mathematics leaders worked to sustain the ambitious mathematics practices through IMP, they also avoided relationships

they thought would threaten the curriculum. It made sense why one administrator called this an “existential conversation” for some to have conversations regarding test scores and graduation competencies; in-group participants feared losing IMP and focusing on improving test scores would also result in a shift away from ambitious mathematics practices. The in-group’s visions, goals, and interactions are reified largely through the curriculum itself.

Expectations of fidelity to the curriculum led many teachers to feel that they lacked ownership of their instruction and failed to meet the needs of their students. Teachers had little opportunity for participation with respect to the curriculum as an artifact of the community of practice. Reified materials (like the IMP curriculum), in order to become meaningful, must be adapted to the local processes of the plan team and the community must work to negotiate meaning of the artifact for it to become useful in practice (Wenger, 1998). Lampert and colleagues (2011) argue for continuous interpretation of the curriculum and response to students that is flexible, not standardized. Ambitious mathematics practices are more sustainable when a variety of resources are drawn upon through the process of using, refining, and developing lessons (Lampert et al., 2011).

If collaboration between colleagues is centered around ambitious mathematics practices, it should meet the same goals that we envision our classrooms. Ambitious mathematics practices emphasize responsiveness to students, a classroom community, high levels of discourse, and the opportunity to solve problems using different strengths (Kazemi et al., 2009; Lampert et al., 2010; Lampert et al., 2011; Leinwand et al., 2014; Rigby et al., 2017; Stein et al., 2008). Teacher collaboration should meet these same

goals: responsiveness, community, high levels of discourse, and problem solving using teachers' different strengths. Productive plan team meetings that focus on reflecting on instruction and resources increase participation. Engagement in practice requires diverse perspectives and competition, challenges, and disagreement are all forms of participation that support participants' learning (Wenger, 1998).

It is understandable that in-group teachers were worried that the focus on test scores would undermine their efforts to support ambitious mathematics practices. Test scores can be a positive or a negative force. For example, test score gains can alter the nature of instruction (Schoenfeld, 2002). Day (2004) illustrated how school reform efforts can have a negative effect on professional identity because many reform measures focus on student achievement. Monitoring student achievement efforts can restrict teachers' working conditions, erode teacher autonomy, destabilize current teaching practices, and increase teacher workload. Furthermore, high stakes testing can distort how assessments are used within the school and often does not support instructional improvement (Garner et al., 2018). During reform efforts focusing on student achievement, administrators tend to steer teachers away from ambitious mathematics practices – emphasizing procedural learning, failing to provide useful information for teachers, and containing questions that can underestimate a students' actual knowledge of mathematics (Leinwand et al., 2014). However, administrators in this study acknowledged these flaws of focusing solely on SAT scores. Administrators wanted to improve test scores while still maintaining alignment between ambitious mathematics practices (e.g., balance of conceptual understanding, procedural fluency, and application) and to the IMP curriculum.

Focusing on raising student achievement is not necessarily synonymous with traditional teaching practices. Mathematically high-achieving schools support academic excellence by making teaching and learning a priority (Kitchen, 2007). Furthermore, not prioritizing instruction and the appropriate use of resources contributes to the opportunity gap, leading to disparities in academic performance (Flores, 2007). Garner and Horn (2018) described a teacher workgroup that used student data to support ambitious mathematics practices. They examined multiple choice data to pick focal students and examined the work of these students closely to make inferences about what the students know and did not know. They then planned instruction beyond simply just reteaching the skill and instead pushed students to think deeper and build their conceptual understanding. Instructional improvement has to work past common data practices through planning additional instruction by interpreting data that is attentive to student thinking (Garner & Horn, 2018). While some studies show the damaging effects of focusing too narrowly on student achievement and test score improvement, other studies provide examples of approaches that embrace both goals simultaneously. In particular, both goals can be met simultaneously when administrators, mathematics leaders, and mathematics teachers share a commitment to ambitious mathematics practices.

So how can schools simultaneously support the development of ambitious mathematics practices while still supporting student achievement? I think back to my first day sitting in the cafeteria with a group of teachers I did not know and discussing Donohoo and colleagues' (2018) article on collective efficacy: "When educators share a sense of collective efficacy... A shared language that represents a focus on student learning as opposed to instructional compliance often emerges... it is their fundamental

task to evaluate the effect of their practice on students' progress and achievement" (p. 42). Maintaining professionalism and professional identity in the face of reform is important; otherwise, reform efforts are unlikely to be successful over the long term. Professionalism can be built through sustained and critical dialogue, mutual trust and respect, and a culture of collaboration and continual improvement; in other words, collective efficacy (Day, 2004; Leinwand et al., 2014; Schoenfeld, 2002). This can be accomplished in three ways. First by acknowledging and building on shared goals and beliefs about ambitious mathematics practices. Second, by allowing all three role groups to share their expertise, recognizing that administrators, mathematics leaders, and mathematics teachers all have different strengths that can support ambitious mathematics practices. Third, by utilizing the structures for dialogue about instructional practices in PLC and plan team meetings. Plan team meetings can build off PLC meetings where all three role groups come together weekly. These opportunities to build collaboration and meaningful reflection about instruction can include critically examining student performance. Collective efficacy depends on all members of the community of practice being full participants.

Reflections on my Role as a Practitioner Researcher

The process of writing a dissertation forced me to reflect on my strongly held beliefs as I examined theory and practice simultaneously. My interests in pursuing my Ph.D. were rooted in applying mathematics education theory into practice and my views of mathematics instruction were largely shaped by the years I spent trying to make theory applicable to my own teaching practices. For many years, my role was largely separated working as a practicing teacher and working in as a student in academia. However,

completing my dissertation research forced me to merge these two roles. I learned that in my role as a practitioner researcher was not objective, as I was positioned between both the power relationships within the school culture and the ideologies of the university (Drake & Heath, 2011). As a result, the boundaries between the two roles were tricky to navigate and my research oftentimes became a political act as I navigated my position on certain issues and sides of arguments. I knew that the practitioner researcher role would be risky but it was also going to be difficult to complete my study while teaching at another school. I believe that being a new teacher at the school while completing my research provided me with insights into the culture and dynamics at play that I would not have understood otherwise. However, there were consequences within the unique relationships I had to form with those who were both participants and colleagues (Drake & Heath, 2011).

I naively thought that I knew the dynamics that affected the support for ambitious mathematics practices and that my research would be straight-forward, aligning both with my own experiences and with findings from previous research. At the beginning of the project, I identified with the leaders in the mathematics department for several reasons. First, I had prior experiences of not feeling supported by administrators who encouraged me to teach more traditionally. Second, my experiences were also reflected in the research, which showed that administrators often did not understand ambitious mathematics practices. Third, it was clear early on in my study that the mathematics leaders did not trust administrators and this influenced my own opinion. Finally, I got off to a rocky start with the principal. I approached the district to ask questions about the research approval process before coordinating with him directly, leaving him a little

blindsided by my desire to complete my dissertation at the school. I also got the sense that he was worried about how my research would further create division in the department. As a result, it took me a few meetings to earn his trust.

Identities shift as an individual moves through different contexts (Wenger, 1998). My perspective began to shift early in the year as my teacher identity began to collide with my researcher identity. It started first when I had difficulty reconciling my experiences with my plan team. Early in the year, when I brought lesson ideas and my previous experiences to the conversation, I often felt brushed aside and was encouraged to adhere to the IMP curriculum. On occasions, I was shut down when asking certain questions. Then, during interviews with several teachers, some expressed the same frustrations that I was feeling. In my own classroom, I struggled with student presentations and knowing the right questions to ask students when they got stuck or were ready for more of a challenge. And after asking for help from the mathematics coach, I felt that I did not receive the support I needed to improve.

Early in the year, conversation about test scores and graduation competencies also began to surface. While I understood the destructive effects of focusing solely on improving test scores, I became aware of the dichotomous discussion happening in the department. I struggled with the position that if I supported ambitious mathematics practices, I had to be against test scores. I noticed the damage that this “either/or” conversation was having on relationships within the department. In order to reconcile this, I returned to my role as a researcher, I had conversations with my dissertation committee members, returned to prior research, and reflected on my own experiences in both the school and academic settings. Through these reflections and conversations, I was

able to rationalize my long-held beliefs about testing and school accountability. The position that I ultimately took was that education always has competing goals and often swings from one end of a continuum to another. However, nothing can be an either/or and eventually, to create the best education possible, we have to find a balance between what appear to be competing goals. However, these goals do not have to be competing at all. These positions started to affect my relationships with the mathematics leaders and other in-group teachers.

As I developed relationships with other colleagues, I became a more active researcher. I found that my own experiences as a teacher were echoed from other participants both in my researcher space and in my teacher space — through both interviews and lunch or happy hour conversations. In both my teacher and researcher roles, it felt cathartic to empathize and share my frustrations with the other teachers. This helped me earn the trust of some of the participants, knowing that I was “on their side.” However, I know that these were ethically important moments (Guillemin & Gillam, 2004). Ethically important moments have important consequences but the researcher may not readily recognize the implications at the time. Ethical consequences were subtle in my interactions with participants and I found that these consequences were difficult to predict and describe (Guillemin & Gillam, 2004). For me, the consequences came later and was one of the causes of strained relationships with mathematics leaders and in-group teachers. They brought their concerns that I was “hanging out with the wrong crowd”.

Researchers must live with the consequences of their research and confidentiality is a continuous challenge that requires renegotiation. Being so closely involved in

practice hinders the researchers' ability to engage with the information and therefore, reflexivity and triangulation is important (Drake & Heath, 2011). Trying to separate my own experiences as a teacher from the knowledge I had acquired from my research, put me in an uncomfortable position. My only option was reflecting and write about my efforts to reconcile the two roles. I did not always maintain these boundaries. There were several examples where those lines between my roles became blurred: getting advice from my evaluator/study participant on how to ask for more support in plan teams, acknowledging to another teacher participant during an interview that I was having the same frustrations, and running for department chair in the summer after I completed my data collection.

The hardest part of being both a teacher and researcher is that you have to critique what you see. It is tough to navigate relationships with colleagues and understand their thoughts and feelings about your research while also working on the same team (Drake & Heath, 2011). Researchers cannot ignore information shared during the research process and can cause discomfort when challenging or criticizing their views. You have to include all voices and ensure that you are not hiding any information. This could be at the cost of some of the relationships that you have established with your colleagues. Some of your colleagues will be open to feedback while others will not. It is a hard conversation to have with someone you have established a relationship with that research might not support what you are doing here, or that I am personally not feeling supported. As an inexperienced researcher, these are tough roles to navigate. As a result, I had to pay special attention to my data analysis and ensure that my own experiences and perspectives were not influencing my research findings. This led me to write many

memos, verify claims by returning to my data over and over again, triangulate with multiple sources, and complete full member checks. I tried to reflect critically on what knowledge was being produced and how it was produced (Guillemin & Gillam, 2004).

The process of making my findings available to a wider audience is part of reflective research (Guillemin & Gillam, 2004). Handing chapter four over to the mathematics leaders for the member-checking process was tough, knowing that it may change any relationship that we had. In-group members were upset and defensive about my findings, particularly around teachers' feelings of judgement and the conversations around test scores. Despite sending them my proposal before beginning the research process, they expected that my research would be more focused around the positive aspects of ambitious mathematics practices and the IMP curriculum where my research goals centered around the relationships within the department. While I have begun to repair my relationship with the mathematics coach as we work closely together on a plan team each day, I have not reconciled my relationships with other in-group members. To conclude, navigating the relationships between participants while being in the role of a practitioner researcher was one of the most difficult parts of the research process. However, I believe that my findings would not have been as dynamic without experiencing the relationships at the high school on a day-to-day basis.

Limitations

Two limitations were apparent in this study. One limitation was the limited data collection opportunities with certain participants in this study. I was actively invited to participate in observation meetings between administrators and mathematics teachers, and therefore had a strong body of data to discuss the relationships between these two

groups of participants. However, in other areas, I was not able to collect as much data as I wanted. Although I continuously ask mathematics leaders if I could observe coaching or post-observation sessions between them and mathematics teachers but I only observed two sessions. Furthermore, I was not invited to observe any interactions between mathematics leaders and administrators. In these two areas, because a majority of my data came from interviews, I found it difficult to reconcile conflicting information from different participants and also had fewer opportunities to triangulate data.

A second limitation related to my position as a teacher and co-worker at the school. With qualitative data collection, there is the possibility that participants will be unwilling to share certain information or might exaggerate information. My dual role as a new teacher and researcher, had the potential to impact my data collection. Participants may not have been as truthful or may have held information back during interviews because of their comfort level. For example, teacher participants' comments on how certain feedback was helpful while still expressing frustration could have been an attempt to be positive about their perceptions of mathematics leaders or administrators. However, if I was a more detached researcher I doubt that I would have been able to develop the same kind of relationships with participants that I did during the course of this study. Therefore, it is possible that participants shared more information because I was able to develop trust outside of the researcher-participant relationship. Opposite of this, other information may have been kept because of my role as a teacher.

Implications for Supporting Ambitious Mathematics Practices

There are several implications from this study for administrators, mathematics leaders, mathematics teacher educators, and researchers. First, this research revealed

certain school structures that allowed administrators to gain an understanding of the instructional goals of the mathematics department. These structures included the academy model in which teachers worked on interdisciplinary teams and had frequent conversations with mathematics teachers, rather than being isolated by department. Also, while this research revealed that administrators were not able to visit classrooms as often as they would have liked due to competing responsibilities, they were able to implement supports for ambitious mathematics practices. For example, this administration supported the mathematics leaders and the department by structuring the schedule to allow for plan teams, arguing for and defending the curriculum, and creating a structure of distributed leadership that allowed mathematics teachers to receive support from leaders in the department. While it is unreasonable to expect administrators at large high schools to be content experts in all subject areas, structures for administrators, content leaders, and teachers to collaborate are possible and will support the development of a greater understanding of mathematics content and department goals.

Second, this study highlighted the difficulty of regular communication between administrators and mathematics leaders while also revealing the utmost importance of mathematics leaders working with administrators to enact the school's instructional goals. Thus, mathematics leaders and administrators should understand the complexities of student achievement while maintaining support for ambitious mathematics practices. Both role groups should ensure open lines of communication, advocate for regular meetings, and support the culture of collective efficacy. Administrators should be the ultimate authority to establish the instructional goals for the school. However, they should partner with mathematics leaders to devise action steps to align the school

instructional goals while still supporting the goals of ambitious mathematics practices. Both regular meetings and time to observe instruction support administrators' development of sophisticated visions of high-quality mathematics instruction, views of students' mathematical capabilities, and the development of shared goals for mathematics instruction.

Third, the mathematics leaders in this study relied on the curriculum to implement ambitious mathematics practices. As a result, they were resistant to conversations that threatened the core of the curriculum and became judgmental when teachers deviated from the curriculum. Thus, mathematics leaders should have training and support to continue to critically examine instructional practices. They should create an environment where teachers feel trusted and are free of judgement. Mathematics leaders should coach and implement structures with teachers that examine the effectiveness of lessons on student learning. They should be open to updating lessons and curriculum resources and rely on the expertise of math teachers to have rich conversations about meeting the needs of all students. Examining instruction requires teachers to identify students' gaps and meet students' needs in various ways. These conversations should include reviewing test scores and student work, continuing to evolve toward understanding and anticipating student thinking, and creating plans for when students do not learn as expected. Mathematics leaders should also advocate for structures to support ambitious mathematics practices (i.e., create a schedule that allows for plan teams and teacher collaboration). Furthermore, because mathematics leaders work closely with teachers, they should be knowledgeable about ambitious mathematics practices and current research and continue to seek opportunities to develop their skills and knowledge.

Finally, tensions can surface between ambitious mathematics practices and student achievement goals. When school goals are in conflict, teachers feel pulled in different directions. While it is important to prepare mathematics teachers to implement ambitious mathematics practices, teacher educators should realize that mathematics teachers are also under pressure to improve test scores. Teachers can be reflective of instruction and student performance while still using instructional practices that support the needs of all students. Using data for “instructional management” and using data for “instructional improvement” are not mutually exclusive (Horn et al., 2015). These practices can include analyzing student data, implementing strategies for intervention for struggling students, and incorporating effective instructional planning. Furthermore, productive teacher collaboration practices can support both the goals of ambitious mathematics practices and student achievement simultaneously. These structures and skills should be introduced and practiced in teacher education programs.

This study revealed the conflicts that can arise when teachers conduct research in schools in which they are also employed. Thus, teacher/researchers should prioritize establishing relationships and identifying as a teacher and colleague. The priority emphasizes the teaching role — working with students, planning lessons, and maintaining other responsibilities — before the researcher role. It is important for teacher/researchers to be taken seriously as a professional by prioritizing the needs of students. Establishing strong relationships and bonds with colleagues can potentially allow for richer data collection. Maintaining trust during the research process requires researchers to be open and honest about research goals and findings with participants. It is important for researchers to understand that consent is an ongoing process and frequent

member checks help establish trust. It is inevitable that boundaries between colleague and researcher will be crossed. The researcher should reflect on these boundaries as a process of reflexivity. Also, reflecting on information shared through data collection versus information shared through conversations between colleagues is crucial. Sometimes information from different sources is hard to separate. This research study revealed potentially important implications for the researcher, teacher educator, mathematics leader, and administrator.

Future Research

While this study explored the support for ambitious mathematics practices in a high school setting, conflicts arose that warrant further exploration. In many schools, particularly high schools, traditional mathematics fails to meet the needs of many students (Cobb & Jackson, 2011; Schoenfeld, 2004). Test score improvement often takes focus away from ambitious mathematics practices. Because of the conflicts that arose in my research between ambitious mathematics practices and test scores, future research should examine schools that both combine ambitious mathematics practices with high student achievement. In addition, research should explore support for ambitious mathematics practices in different school settings. This single case study focused on a suburban high school with relatively low racial and socio-economic diversity. It is important to study the extent of support for ambitious mathematics practices in schools that face greater challenges to improve student achievement or close the opportunity gap. Finally, it would be important to know how the challenges that high schools face in implementing ambitious mathematics practices compared to those faced by middle schools or elementary schools.

Reflections

It is important to keep in mind that conversations about instruction are at the heart of both student achievement and ambitious mathematics practices. Focus on instructional improvement has been spurred by educational reform efforts that typically focus on improvement in test scores; however, high-quality mathematics instruction is also important when addressing goals for instructional improvement (Cobb & Jackson, 2011). If we ignore one goal at the expense of another, the goal of ambitious mathematics practices is likely to falter. In the high school selected for this study, supporting ambitious mathematics practices involved many different facets—the evaluation cycle, coaching, plan teams, and collaboration across various role groups. Supporting ambitious mathematics practices in the context of reform pressures such as meeting graduation competencies and raising test scores, is difficult but can be accomplished through collaborative relationships among administrators, mathematics leaders, and mathematics teachers. I hope that this research provides lessons learned in supporting ambitious mathematics practices for all schools and that future research will continue to explore what successful support for ambitious mathematics practices could look like.

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APPENDIX A: DRAFT OF CONSENT FORM

University of Denver Consent Form for Participation in Research

Title of Research Study: Sustaining Change: Supporting Ambitious Mathematics Practices in High School

Researcher: Jacklyn VanOoyik, Ph.D. Candidate, The University of Denver
Faculty Advisor: Garrett Roberts, PhD, Assistant Professor, The University of Denver

Purpose: You are being asked to participate in a research study to better understand your experiences in working with mathematics instruction. The purpose of this research is to examine how ambitious mathematics practices are developed, supported, and sustained within a high school and the roles and responsibilities of school leaders that contribute to that change. Please read the information below and ask any questions about participation.

Procedures: If you agree to participate in this research study, you will be invited to sit for two interviews, scheduled at a time of your convenience. The interviews will ask you about your experiences with mathematics instruction at your school and will last approximately one hour. In addition, you will be asked to participate in an observation of your daily routines that will last between a half day and a full day. This observation could include a coaching or evaluation meeting between teachers and school leaders. Observations will also be scheduled at a time of your convenience.

Voluntary Participation: Participating in this research study is completely voluntary. Even if you decide to participate now, you may change your mind and stop at any time. You may choose not to answer an interview question or decline to be observed for any reason without penalty or other benefits to which you are entitled.

Risks or Discomforts: Potential risks and/or discomforts of participation are minimal. However, questions or conversations may include negative feelings or stress when answering questions or participating in an observation.

Benefits: Possible benefits of participation include a better and more opportunities to collaborate and work together with colleagues.

Confidentiality: The researcher will ensure that information is secure and unidentifiable throughout the time of the research and after research is completed. In order to keep your information safe throughout this study, all data will be stored in a password-protected, secure computer and only the primary researcher will have access to any data collected or provided. Your individual identity will be kept private when information is presented or published about this study through the use of a pseudonym. In addition, You will be audio-recorded during interviews and at times during observations. Transcriptions will be stored on password-protected, secure computer and audio files will be destroyed at the conclusion of the research project.

However, should any information contained in this study be the subject of a court order or lawful subpoena, the University of Denver might not be able to avoid compliance with the order or subpoena. The research information may be shared with federal agencies or local committees who are responsible for protecting research participants, including individuals on behalf of The University of Denver.

Questions: If you have any questions about this project or your participation, please feel free to ask questions now or contact Jacklyn VanOoyik at 303-549-6252 or jacklyn.vanooyik@du.edu at any time. You can also contact Garrett Roberts, PhD at garrett.roberts@du.edu.

If you have any questions or concerns about your research participation or rights as a participant, you may contact the DU Human Research Protections Program by emailing IRBAdmin@du.edu or calling (303) 871-2121 to speak to someone other than the researchers.

Options for Participation

Please initial your choice for the options below:

___ The researchers may audio/video record or photograph me during this study.

___ The researchers may NOT audio/video record or photograph me during this study.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

Participant Signature

Date

Printed Name

APPENDIX B: FIRST INTERVIEW PROTOCOL WITH SCHOOL LEADERS

Thank you for taking the time to meet with me today. I am [researcher name]. Today is [day], [month] [date], [year] and I am interviewing [participant]. The reason why I have asked you to participate in this interview is to understand your experiences in working with mathematics teachers.

I am going to spend the next hour or so asking you questions about your experiences in working with the mathematics department. The consent form that you signed means that I can record and transcribe this interview. Do you still agree to this? I will also be taking notes during this time. The data from this interview will be used for a dissertation report and could be published. This interview tape or transcript will not be accessible to anyone but me and will be stored in a secure digital location. The information you share will not be shared with any other participant or employee at this school connected to your identity at any point in time.

Do you have any questions before we begin?

First, I would like to know a little bit about your background.

Question 1

Can you please tell me your name and the role that you play at the school?

- Do you have a preferred pseudonym that you would like me to use for the results of this research?

Question 2 (research sub-question 1)

Please tell me about your previous experience as a classroom teacher and a school leader.

- What is your background and education?
- In what content areas have you worked?
- What are your views about teaching in this content area(s)?
- What are your experiences in teaching mathematics?

Question 3 (research sub-question 1)

Tell me about your experience here at this school.

- How long have you worked here?
- What roles have you played?
- What do you like about working at this school?
- What are the biggest challenges you face in your role?
- What has changed about your role since you started?

Question 4 (research sub-question 1)

Tell me about your work with the mathematics department.

<ul style="list-style-type: none"> • How do you work with mathematics teachers? • How often do you interact with mathematics teachers? • How often do you work with the mathematics coach or department chair OR admin? • How often do you attend meetings within the mathematics department or with mathematics teachers?
Question 5 (research sub-question 1) What would you say are the shared goals of the mathematics department?
<i>Next, I want to know more about your role in supervising or evaluating classroom teachers.</i>
Question 6 (research sub-question 1) Describe your current responsibilities for supervising classroom teachers. <ul style="list-style-type: none"> • What departments or programs do you currently supervise? • How many teachers do you currently supervise?
Question 7 (research sub-question 1 and 2) Describe how you supervise classroom instruction. <ul style="list-style-type: none"> • What classroom conditions do you look for when completing an observation? • What types of instructional activities do you try to observe? • How do you interact with students during your observation? • How do you interact with classroom teachers prior to, during, or after your observation? • Are there any barriers you have to effectively supervise teachers?
Question 8 (research sub-question 1 and 2) What does an effective lesson in math look like to you? <ul style="list-style-type: none"> • What is the teacher doing or saying? • What are the students doing or saying? • What evidence are you looking for when observing an effective lesson? • What do you believe makes a good math lesson?
Question 9 (research sub-question 2) What feedback do you provide to mathematics teachers after completing your observation? <ul style="list-style-type: none"> • How is this feedback provided? • What is the focus of your feedback about? • Do you plan any follow up support or activities for teachers? What does this look like?
Question 10 (research sub-question 2)

<p>Describe a conversation that you've had with a mathematics teacher whose instruction you felt was adequate or met your expectations.</p> <ul style="list-style-type: none"> • Are teachers perceptive?
<p>Question 11 (research sub-question 2)</p> <p>Describe a conversation that you have had with a mathematics teacher whose instruction you felt was inadequate or did not meet your expectations.</p> <ul style="list-style-type: none"> • Are teachers perceptive?
<p>Question 12 (research sub-question 2) <i>Administrators Only</i></p> <p>To what extent does the feedback you provide differ between content areas?</p> <ul style="list-style-type: none"> • How does feedback from other content areas differ from feedback in mathematics? • What do you think explains these differences?
<p>Question 13 (research sub-question 2)</p> <p>Apart from your classroom observations, what other types of data do you use to monitor instruction in the mathematics department or program?</p> <ul style="list-style-type: none"> • How do you use this information? • How does this information inform the conversations or feedback you provide to teachers?
<p>Question 14A (research sub-question 2) <i>Administrators Only</i></p> <p>How do you work with the mathematics department chair or the mathematics coach to support teachers?</p> <ul style="list-style-type: none"> • What does this look like? • How often do you work with the mathematics leaders? • Do you communicate the goals for a teacher to the mathematics department? • Do you feel that the leaders in the mathematics department are supportive of school goals? <p>Question 14B (research sub-question 2) <i>Mathematics Leaders Only</i></p> <p>How do you work with administrators to support teachers?</p> <ul style="list-style-type: none"> • What does this look like? • How often do you work with administrators? • Do you communicate the goals for a teacher to an administrator? • Do you feel that the administrators are supportive of the mathematics department goals?
<p>Question 15</p> <p>Is there anything else you would like to share at this time?</p>
<p><i>Thank you again for taking the time to meet with me. If you have any additional information you think you would want to share, you can email me at the email listed on your copy of the consent form. I have a few more questions to ask you.</i></p>

- *When reading your interview, is there anything that you would like me to think about or pay attention to?*
- *Would you be interested in obtaining a copy of the transcript?*
- *If I have additional questions for you that come up during the course of the study, would you be willing to sit for a follow up interview?*
- *As a part of the collaborative research process, I may be sending you part of my data analysis to verify that I have portrayed the information that you have shared with me in a truthful way. Would this be alright with you?*
- *Are there any other ways that you would like to be involved in this research project or ideas of something that might be of interest for the research?*

APPENDIX C: SECOND INTERVIEW PROTOCOL WITH SCHOOL LEADERS

Thank you for taking the time to meet with me today. I am [researcher name]. Today is [day], [month] [date], [year] and I am interviewing [participant]. The reason why I have asked you to participate in this interview is to understand your experiences in working with leaders at this school.

I am going to spend the next hour or so asking you questions about your views about math teaching and learning. The consent form that you signed means that I can record and transcribe this interview. I will also be taking notes during this interview. The data from this interview will be used for a dissertation report and could be published. This interview tape or transcript will not be accessible to anyone but me and will be stored in a secure location. The information from this interview will not be shared with any other participant or employee at this school during the time of this research project or after research is completed.

Do you have any questions before we begin?

First, I would like to ask you about your views about mathematics instruction.

Question 1 (research sub-question 1)

When observing a teacher's math classroom for one or more lessons, what would you look for to decide whether the mathematics instruction is high quality?

- Probe for participant description.
- When you say student engagement, engaged in what?
- Why do you think that is important? (to work in groups, whole class discussion, etc.)
- What is the content of student talk or teacher talk?
- What kinds of questions would you anticipate hearing?
- What are some of the things you would expect to find the teacher doing in the classroom?
- What kinds of problems or tasks would you expect to see the students working on? What is the structure of the lesson?
- What would a classroom discussion sound like? Would the entire class be participating or just a small group?
- What would the introduction to the lesson look like?

Next, I would like to ask you about your views about students' math capabilities.

Question 2 (research sub-question 1)

In a teacher's classroom, when students don't learn as expected, what do you find to be the typical reasons?

- What behaviors or characteristics would you ascribe to different groups?

<ul style="list-style-type: none"> • Are all students motivated when you observe classrooms? • Why do you think they are not motivated? • Do you have any concerns about the low performing students in these classes? • What is the source of the problem for low motivation or low performance?
<p>Question 3 (research sub-question 1) (Connect back to categories of students from the last question) Do you feel that teachers should adjust their instruction for different groups of students?</p> <ul style="list-style-type: none"> • Why or why not? • For which groups of students? • How should a teacher adjust their instruction? • How should students be grouped?
<p>Question 4 (research sub-question 1) So far this year, have you provided instructional support or feedback to help a teacher work with groups of low performing students?</p> <ul style="list-style-type: none"> • Can you describe the support or feedback you provided? • Did these supports help the teacher?
<p>Question 5 Is there anything else you would like to share at this time?</p>
<p><i>Thank you again for taking the time to meet with me. If you have any additional information you think you would want to share, you can email me at the email listed on your copy of the consent form. I have a few more questions to ask you.</i></p> <ul style="list-style-type: none"> • <i>When reading your interview, is there anything that you would like me to think about or pay attention to?</i> • <i>Would you be interested in obtaining a copy of the transcript?</i> • <i>If I have additional questions for you that come up during the course of the study, would you be willing to sit for a follow up interview?</i> • <i>As a part of the collaborative research process, I may be sending you part of my data analysis to verify that I have portrayed the information that you have shared with me in a truthful way. Would this be alright with you?</i> <p><i>Are there any other ways that you would like to be involved in this research project or ideas of something that might be of interest for the research?</i></p>

APPENDIX D: FIRST INTERVIEW PROTOCOL WITH MATHEMATICS TEACHERS

<p><i>Thank you for taking the time to meet with me today. I am [researcher name]. Today is [day], [month] [date], [year] and I am interviewing [participant]. The reason why I have asked you to participate in this interview is to understand your experiences in working with leaders at this school.</i></p> <p><i>I am going to spend the next hour or so asking you questions about your experiences as a mathematics teacher here. The consent form that you signed means that I can record and transcribe this interview. I will also be taking notes during this interview. The data from this interview will be used for a dissertation report and could be published. This interview tape or transcript will not be accessible to anyone but me and will be stored in a secure location. The information from this interview will not be shared with any other participant or employee at this school during the time of this research project or after research is completed.</i></p> <p><i>Do you have any questions before we begin?</i></p>
<p><i>First, I would like to know a little bit about your background.</i></p>
<p>Question 1</p> <p>Can you please tell me your name and the role that you play at the school?</p> <ul style="list-style-type: none"> • Do you have a preferred pseudonym that you would like me to use for the results of this research?
<p>Question 2 (research sub-question 1)</p> <p>Please tell me about your previous experience as a classroom teacher.</p> <ul style="list-style-type: none"> • What is your background and education? • In what content areas have you worked? • What are your experiences in teaching mathematics? • What are your views about teaching about mathematics?
<p>Question 3 (research sub-question 1 and 3)</p> <p>Tell me about your experience here at this school.</p> <ul style="list-style-type: none"> • How long have you worked here? • What roles have you played? • What do you like about working at this school? • What are the biggest challenges you face in your role? • What has changed about your role since you started?
<p>Question 4 (research sub-question 3)</p>

<p>Tell me what it's like to be a teacher in this school/department.</p> <ul style="list-style-type: none"> • How do you think your experience as a teacher in this department differs from that of your colleagues? • How do you think your experience as a teacher in this department differs from that of other schools? • Are there any barriers to be the best teacher you can be?
<p>Question 5 (research sub-question 1)</p> <p>What would you say are the shared goals of the math department?</p> <ul style="list-style-type: none"> • What is the vision of high-quality math instruction?
<p><i>Next, I am going to ask you some questions about the leaders in the math department.</i></p>
<p>Question 6 (research sub-question 2)</p> <p>How often do you interact with the math coach or the math department chair?</p> <ul style="list-style-type: none"> • What contexts do you interact with them? • Are they supportive of your goals and the goals of the math department? • How are the coach and department chair involved in meetings with your department colleagues?
<p>Question 7 (research sub-question 1 and 2)</p> <p>Describe how the mathematics coach and mathematics department chair in this school supervise your instruction.</p> <ul style="list-style-type: none"> • How do you think their previous experiences influences their supervision of you and/or your colleagues?
<p>Question 8 (research sub-question 2)</p> <p>What feedback do you receive from the mathematics coach and mathematics department chair?</p> <ul style="list-style-type: none"> • In what form or forum is the feedback provided? • What does the feedback typically focus on? • Is the feedback you receive from them valuable? • Can you provide specific examples?
<p>Question 9 (research sub-question 3)</p> <p>How does the feedback you receive from the mathematics coach and mathematics department chair help you improve your instructional practice?</p> <ul style="list-style-type: none"> • Does the mathematics coach or department chair provide follow up activities or additional support for the feedback you receive?
<p>Question 10 (research sub-question 3)</p>

<p>Can you recall an exchange with an administrator in which you received feedback that helped you improve some aspect of your practice (e.g. delivery of content, pedagogy, classroom management, etc.)?</p> <ul style="list-style-type: none"> • How was this exchange different from or similar to other exchanges you have had with the administrators who supervise you? • How was this exchange different than with past administrators you have worked with at other schools?
<p><i>Next, I want to know more about working with administrators at the school.</i></p>
<p>Question 11 (research sub-question 2)</p> <p>How often do you interact with the administration at this school?</p> <ul style="list-style-type: none"> • What contexts do you interact with them? • Are they supportive of your goals and the goals of the math department? • How are administrators involved in meetings with your department colleagues?
<p>Question 12 (research sub-question 1 and 2)</p> <p>Describe how the administration in this school supervises your instruction.</p> <ul style="list-style-type: none"> • Was your supervisor formerly a mathematics teacher? • How do you think this influences their supervision of you and/or your colleagues?
<p>Question 13 (research sub-question 2)</p> <p>What feedback do you receive from the administrator (e.g. principal or assistant principal) who supervises you?</p> <ul style="list-style-type: none"> • In what form or forum is the feedback provided? • What does the feedback typically focus on?
<p>Question 14 (research sub-question 3)</p> <p>How does the feedback you receive from the administration help you improve your instructional practice?</p> <ul style="list-style-type: none"> • Does the administrator provide follow up activities or additional support for the feedback you receive?
<p>Question 15 (research sub-question 3)</p> <p>To what extent does the feedback you receive from administrators reflect or address your content area?</p> <ul style="list-style-type: none"> • Can you give me a specific example of an administrator providing you with feedback that was related to your content area? • How was the feedback similar to or different from the other feedback you receive?
<p>Question 16 (research sub-question 3)</p>

<p>Can you recall an exchange with an administrator in which you received feedback that helped you improve some aspect of your practice (e.g. delivery of content, pedagogy, classroom management, etc.)?</p> <ul style="list-style-type: none"> • How was this exchange different from or similar to other exchanges you have had with the administrators who supervise you? • How was this exchange different than with past administrators you have worked with at other schools?
<p>Question 17</p> <p>Do you receive feedback from anyone else on your instruction?</p>
<p>Question 18</p> <p>Is there anything else you would like to share at this time?</p>
<p><i>Thank you again for taking the time to meet with me. If you have any additional information you think you would want to share, you can email me at the email listed on your copy of the consent form. I have a few more questions to ask you.</i></p> <ul style="list-style-type: none"> • <i>When reading your interview, is there anything that you would like me to think about or pay attention to?</i> • <i>Would you be interested in obtaining a copy of the transcript?</i> • <i>If I have additional questions for you that come up during the course of the study, would you be willing to sit for a follow up interview?</i> • <i>As a part of the collaborative research process, I may be sending you part of my data analysis to verify that I have portrayed the information that you have shared with me in a truthful way. Would this be alright with you?</i> • <i>Are there any other ways that you would like to be involved in this research project or ideas of something that might be of interest for the research?</i>

APPENDIX E: SECOND INTERVIEW PROTOCOL WITH MATHEMATICS TEACHERS

Thank you for taking the time to meet with me today. I am [researcher name]. Today is [day], [month] [date], [year] and I am interviewing [participant]. The reason why I have asked you to participate in this interview is to understand your experiences in working with leaders at this school.

I am going to spend the next hour or so asking you questions about your views about math teaching and learning. The consent form that you signed means that I can record and transcribe this interview. I will also be taking notes during this interview. The data from this interview will be used for a dissertation report and could be published. This interview tape or transcript will not be accessible to anyone but me and will be stored in a secure location. The information from this interview will not be shared with any other participant or employee at this school during the time of this research project or after research is completed.

Do you have any questions before we begin?

First, I would like to ask you about your views about mathematics instruction.

Question 1 (research sub-question 1)

If you were asked to observe a teacher's math classroom for one or more lessons, what would you look for to decide whether the mathematics instruction is high quality?

- Probe for participant description.
- When you say student engagement, engaged in what?
- Why do you think that is important? (to work in groups, whole class discussion, etc.)
- What is the content of student talk or teacher talk?
- What kinds of questions would you anticipate hearing?
- What are some of the things you would expect to find the teacher doing in the classroom?
- What kinds of problems or tasks would you expect to see the students working on?
- What would a classroom discussion sound like? Would the entire class be participating or just a small group?
- What would the introduction to the lesson look like?

Next, I would like to ask you about your views about students' math capabilities.

Question 2 (research sub-question 1)

In your own classroom, when students don't learn as expected, what do you find to be the typical reasons?

<ul style="list-style-type: none"> • What behaviors or characteristics would you ascribe to different groups? • Are all students motivated in your classrooms? • Why do you think they are not motivated? • Do you have any concerns about the low performing students in your classes? • What is the source of the problem for low motivation or low performance?
<p>Question 3 (research sub-question 1) (Connect back to categories of students from the last question) Do you feel that you need to adjust your instruction for different groups of students?</p> <ul style="list-style-type: none"> • Why or why not? • For which groups of students? • How should you adjust your instruction? • How should students be grouped?
<p>Question 4 (research sub-question 1) So far this year, have you received instructional support or feedback to help you work with groups of low performing students?</p> <ul style="list-style-type: none"> • Can you describe the support or feedback you received? • Were these provided by the district, school, administrator, or coach? • Did these supports help you in your classroom?
<p>Question 5 Is there anything else you would like to share at this time?</p>
<p><i>Thank you again for taking the time to meet with me. If you have any additional information you think you would want to share, you can email me at the email listed on your copy of the consent form. I have a few more questions to ask you.</i></p> <ul style="list-style-type: none"> • <i>When reading your interview, is there anything that you would like me to think about or pay attention to?</i> • <i>Would you be interested in obtaining a copy of the transcript?</i> • <i>If I have additional questions for you that come up during the course of the study, would you be willing to sit for a follow up interview?</i> • <i>As a part of the collaborative research process, I may be sending you part of my data analysis to verify that I have portrayed the information that you have shared with me in a truthful way. Would this be alright with you?</i> <p><i>Are there any other ways that you would like to be involved in this research project or ideas of something that might be of interest for the research?</i></p>

APPENDIX F: VISIONS OF HIGH-QUALITY MATHEMATICS INSTRUCTION RUBRICS

Level	Potential ways of characterizing teacher's role	Examples
4 Teacher as <i>more knowledge- able other</i>	<i>Influencing classroom discourse:</i> Suggests that the teacher should purposefully intervene in classroom discussions to elicit and scaffold students' ideas, create a shared context, and maintain continuity over time (Staples, 2007).	Teacher plays a proactive role in supporting/scaffolding students' talk: "When [teachers] pose a question and a student answers, they don't say yes this is how it is always done. They ask the kids to explain how they came up with the answer, ask for other students to explain how they came up with the answer, present all the ideas to the student and ask them if these are good procedures for answering types of problems like this and talk about student preference —'Do you like one way more than another and does this way make sense?'— so that the kids can build their own frame of reference to the material." If students "start to say something but hesitate I'll say, 'Say more,' or, 'tell me why you thought it was this way.' I'll try and bring in other kids, 'Do you agree with what they said? Why?'"
	<i>Attribution of mathematical authority:</i> Suggests that the teacher should support students in sharing in authority (Lampert, 1990), problematizing content (Hiebert et al., 1996), working toward a shared goal (Hiebert et al., 1997), and ensuring that the responsibility for determining the validity of ideas resides with the classroom community (Simon, 1994).	Teacher uses students' explanations, responses, questions, and problems as lesson content (Fraivillig et al., 1999); "Students should be involved in the learning process as far as asking questions and being able to maybe actually give examples and working them and talking to the teacher about them." Teacher keeps students positioned as the thinkers and decision-makers (Staples, 2007); "When kids are getting stuck are you [the teacher] just pulling them out or are you asking those questions that press students to think even deeper so that they figure out the problem that they become the problem-solvers?"
	<i>Conception of typical activity structure:</i> Promotes a "launch-explore-summarize" lesson (Madsen-Nason & Lappan, 1987), in which (a) the teacher poses a problem and ensures that all students understand the context and expectations (Jackson et al., 2013), (b) students develop strategies and solutions (typically in collaboration with each other), and (c) through reflection and sharing, the teacher and students work together to explicate the mathematical concepts underlying the lesson's problem (Stigler & Hiebert, 1999).	Teacher facilitates the process of students working together to solve problems and then share explanations. "Students are the ones doing most of the work and they're defending their answers and they are challenging each other."

Figure 1. VHQM Rubric: Role of the Teacher (abbreviated)

<p>3</p> <p>Teacher as facilitator</p>	<p><i>Influencing classroom discourse:</i> Describes the teacher facilitating student-to-student talk, but primarily in terms of students taking turns sharing their solutions; hesitates to “tell” too much for fear of interrupting the “discovery” process (Lobato, Clarke, & Ellis, 2005).</p>	<p>Teacher asks students about other students’ work, or to be prepared to ask their own questions about other students’ work (Hufferd-Ackles et al., 2004) but does not articulate a rationale for such teacher moves in terms of supporting the development of a discourse community; instead, the teacher “facilitates” question/answer time after student presentations, without intervening to highlight key mathematical ideas and possibly concluding by telling the class the “correct” solution/strategy.</p>
	<p><i>Attribution of mathematical authority:</i> Supports a “no-tell policy”: Stresses that students should figure things out for themselves and play a role in “teaching.” Suggests that if students are pursuing an unfruitful path of inquiry or an inaccurate line of reasoning, the teacher should pose a question to help them find their mistake, but the reason for doing so focuses more on not telling than helping students develop mathematical authority. Is open to students developing their own mathematical problems, but these inquiries are not candidates for paths of classroom mathematical investigation.</p>	<p>“[Students are] not waiting all the time for the teacher [to] come and spoon-feed them but doing investigating on their own, coming up with ah-has on their own or coming up with ‘what if this’?—that’s when I think they’re really learning.”</p> <p>Teacher helps students find their own mistakes. If students are headed “down the wrong path,” the teacher should “ask them something else to put them back on the right track” (no rationale for such a teacher move in terms of supporting the development of mathematical authority).</p> <p>Teacher “prompts class but does not lead the class” (no “spoon-feeding”); Teacher “answers questions with questions.”</p>
	<p><i>Conception of typical activity structure:</i> Promotes a “launch-explore-summarize” lesson (Madsen-Nason & Lappan, 1987), in which (a) the teacher poses a problem and possibly completes the first step or two with the class or demonstrates how to solve similar problems, (b) students work (likely in groups) to complete the task(s), and (c) students take turns sharing their solutions and strategies and/or the teacher clarifies the primary mathematical concept of the day (i.e., how they “should have” solved the task).</p>	<p>“It depends on the topic that you are presenting. Some topics the teacher may have to present and then other topics it’s better to let the kids explore.”</p> <p>Teacher actively engaging students in figuring problems out “helps them remember it a little bit better than just a teacher up there talking about it.”</p> <p>“The kids are pretty much teaching themselves. The teacher’s just kind of up there facilitating and making sure that their light bulbs are turning on.”</p>

Figure 1. VHQM Rubric: Role of the Teacher (abbreviated). (Continued)

2 Teacher as monitor	<i>Influencing classroom discourse:</i> Suggests the teacher should promote student-to-student discussion in group work.	Teacher should encourage students to “ask each other for help.”
	<i>Attribution of mathematical authority:</i> Suggests a view of teacher as an “adjudicator of correctness” (Hiebert et al., 1997). Students may participate in “teaching” but only as mediators of the teacher’s instruction, adding clarification, etc. If students are pursuing an unfruitful path of inquiry or an inaccurate line of reasoning, the teacher stops them and sets them on a “better” path.	<p>“[If] a kid understands the way to explain it better than I do, I give the floor to them as long as it makes sense”; A student who “gets it” should come to board and teach—”Having a kid who’s really good at the math, but who’s still at their [peers’] level, sometimes they can explain it a little bit better [than the teacher].”</p> <p>If the students are going down a direction that looks like it’s a dead-end, “the teacher needs to circle the wagons, regroup, ‘Oh guys this is not working out. We need to back up cause, cause we’re going the wrong way. So let’s back up. Let’s try this a different way.’”</p>
	<i>Conception of typical activity structure:</i> Promotes a two-phase, “acquisition and application” lesson (Stigler & Hiebert, 1999), in which (a) the teacher demonstrates or leads a discussion on how to solve a type of problem and then (b) students are expected to work together (or “teach each other”) to use what has just been demonstrated to solve similar problems while the teacher circulates throughout the classroom, providing assistance when needed.	<p>The teacher should “show [students] examples [of] how to do it and why are they doing it, what is the purpose of it. Then, do the facilitation, walk around, see the group work”; “Students acting as leaders”; “Students should be teaching each other.”</p> <p>Teacher should be “up, moving around, looking at students’ work, helping them as they work”; Teacher should not “lecture the whole time.”</p>

Figure 1. VHQM Rubric: Role of the Teacher (abbreviated). (Continued)

1 Teacher as deliverer of knowledge	<i>Influencing classroom discourse:</i> Focuses exclusively on teacher-to-student discourse. Considers quality of teacher's explanations in terms of clarity and mathematical correctness.	<p>"Teacher should be mathematically correct"; "no steps skipped."</p> <p>"Explain why and how it's used in everyday life, not just formulas."</p>
	<i>Attribution of mathematical authority:</i> Suggests that the responsibility for determining the validity of ideas resides with the teacher or is ascribed to the textbook (Simon, 1994). (This includes insistence that teachers be mathematically knowledgeable and correct.)	<p>Teacher "should explain it so it makes sense"; "The teacher needs to be factually accurate"; "I would look and see that the teacher seems to know what he or she's talking about."</p> <p>Teacher "should answer all student questions"; "If there's a misconception is the teacher correcting it or letting it go?"</p>
	<i>Conception of typical activity structure:</i> Promotes efficiently structured lessons (in terms of coverage) in which the teacher directly teaches how to solve problems. Periods might include time for practice while teacher checks students' work and answers questions, but this is likely quiet and individually based with no opportunity for whole-class discussion. Description suggests no qualms with exclusive lecture format.	<p>"Teacher provides clear instructions, clear assignment, examples shown, students being walked through a problem"; "Most of the time the teacher teaches it and the students take it in. If they have any question about it, then they should feel free to ask."</p> <p>Teacher has a task to accomplish—to present the lesson planned—and must see that it is accomplished without digressions from, or inefficient changes, in the plan (Thompson, 1984).</p>
0 Teacher as motivator		<p>Looks to see "whether the teacher has the dynamics that the kids need." Looks for "the teacher's enthusiasm"; "Some teachers are obviously more charismatic than others."; "It is more about being an entertainer than it is a teacher."</p> <p>Looks for teacher "making connections [to students]. Some people are just naturally very good at teaching."</p>

Figure 1. VHQM Rubric: Role of the Teacher (abbreviated). (Continued)

Level	Patterns/structure of classroom talk		Nature of classroom talk	
	Description	Example(s)	Description	Example(s)
4	Promotes whole-class conversations, including student-to-student talk that is student-initiated, not dependent on the teacher (Hufferd-Ackles et al., 2004); promotes developing and supporting a “mathematical discourse community” (Lampert, 1990).	“A child will come up and show their work and a different child explain what they did to solve it. And then the children actually question each other, ‘Well I didn’t see where you got that three from, can you show me where did it come from?’ or, ‘Why did you do it this way instead of this way?’ They’re communicating with each other and the teacher’s more of a facilitator.”	Suggests that classroom talk should be conceptually oriented—including articulating/refining conjectures and arguments for explaining mathematical phenomena—for the purpose of supporting students in “doing mathematics” and/or spawning new investigations.	<p>Classroom talk should comprise mathematical arguments, relations among multiple strategies, exploration of errors/contradictions (Kazemi & Stipek, 2001)</p> <p>Student discussions should spawn new questions and help students recognize confusions (Engle & Conant, 2002)</p> <p>Students hold others accountable for producing sufficient mathematical arguments by repeating their own or others’ questions until satisfied with answers (Hufferd-Ackles et al., 2004)</p>

Figure 2. VHQM Rubric: Classroom Discourse (abbreviated).

3	<p>Promotes whole-class conversations (about ideas, not just whole-class lecture or task set-up), but description places the teacher at the center of talk, likely doing most of the prompting and pressing, or calling upon students/groups to take turns presenting their strategies.</p>	<p>Describes a view of students asking questions of one another's work on the board, but likely at the prompting of the teacher, where students usually give information when probed by the teacher with some volunteering of thoughts (Hufferd-Ackles et al., 2004).</p> <p>"[In] classroom discussion I would expect the teacher to throw out a question as a facilitator and then I would expect the students to somewhat lead that discussion. 'This is how we got to this; this is your next step. This is the next step,' in these different groups raising their hands and telling what the next steps and how to solve a problem are. So I would think that again the teacher would be the facilitator and the students would be kind of leading the discussion."</p>	<p>Insists that the content of classroom talk be about mathematics (e.g., asking questions, providing explanations), but description of such talk either (a) characterizes talk that is of a calculational orientation or (b) fails to specify expectations for the nature/quality of the questions, explanations, etc.</p>	<p>"Kids speaking to each other in mathematical vocabulary, talking about their thinking processes."</p> <p>"The kids are not just compliant and sitting there working quietly, they are actually arguing passionately about the mathematics."</p> <p>Describes <i>accountable talk</i> by referring to protocols—"explaining why, disagreeing, and defending answers" or "if [students] disagree, instead of yelling out, 'You're wrong,' they'll say, 'I disagree because I think you should try this way'"—but does not describe the function that such protocols play in terms of supporting students' development of mathematical authority or orientation to mathematics.</p>
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Figure 2. VHQM Rubric: Classroom Discourse (abbreviated). (Continued)

2	Promotes student-student discourse but describes it exclusively in the context of small group/partner work (if there's mention of whole-class discussion, it's characterized only as an option, not a vital element).	<p>"The larger the discussion, usually the harder it is for them to discuss. More than likely it's teacher-led discussion . . . I like for them to actually discuss with their partner."</p> <p>Students should "engage with each other."</p> <p>"Students should ask each other questions instead of asking the teacher."</p>	Insists that the content of students' classroom talk (with each other) be about mathematics, but provides no description of content (i.e., does not specify things such as questions and explanations).	<p>"You would see students talking among themselves in a controlled manner about mathematics that's being taught that day or that's been taught previous to that."</p> <p>Students should be "actually talking about math."</p> <p>Describes accountable talk as "taking turns, being polite."</p>
1	Describes traditional lecturing and/or IRE (Mehan, 1979), or IRF (Sinclair & Coulthard, 1975) dialogue patterns. (Note that this can occur in a "whole-class" setting, but is not considered a genuine whole-class discussion.)	<p>"Most of the time the teacher teaches it and the students kind of take it in . . . there's not a lot of room for debate on the math because, you know, this is it."</p> <p>Students "could answer the questions you ask" (i.e., in an IRE pattern, the teacher's questions are clear and answerable).</p>		

Figure 2. VHQM Rubric: Classroom Discourse (abbreviated). (Continued)

Level	Description	Example(s)
4	Emphasizes tasks that have the potential to engage students in “doing mathematics” (Stein et al., 1996; Smith & Stein, 1998), allowing for “insights into the structure of mathematics” and “strategies or methods for solving problems” (Hiebert et al., 1997).	<p>Students should be engaged in challenging questions that have ambiguous or multiple routes to a solution in order to generate multiple solution paths and strategies for discussing/comparing, thus promoting students’ flexibility in applying problem-solving strategies (Russell, 2000).</p> <p>“Questions that pertain to their lives around them or connected to things they’ve done in previous days . . . and require the kids to learn a concept not just by being told what it is and how to do it but to actually think about what it is they were doing and then coming up with the why or ‘Oh look, this worked for all these problems, so is this gonna work for all of our problems?’ . . . do some critical thinking.”</p>
3	Emphasizes tasks that have the potential to engage students in complex thinking, including tasks that allow multiple solution paths or provide opportunities for students to create meaning for mathematical concepts, procedures, and/or relationships. “Application” is characterized in terms of problem solving. However, tasks described lack complexity, do not press for generalizations, do not emphasize making connections between strategies or representations, or require little explanation (Boston, 2012). Instead, they emphasize connections to “the real world” or “prior knowledge.” Reasons for multiple strategies are not tied to rich discussion or making connections between ideas.	<p>Tasks should have “more than one solution or maybe different ways to approach it so that different ideas are accepted and could be possible.”</p> <p>“A problem can be solved different ways, because there are different ways of thinking and kids need to know that there’s not just one set way to do things.”</p> <p>“Have multiple entry points for students, multiple solution tasks that require children to really think and put a lot of information together in order to answer the question.”</p> <p>“Open-ended so it doesn’t have a right answer, and it talks about how things fit together instead of what the answer is (e.g., ‘Give me some starting and ending points that could be a vector of positive 5’).”</p> <p>“I would look for tasks that accessed some sort of prior knowledge yet took the kids a little bit further to build on that knowledge.”</p> <p>“I want to see a lot of different ways of doing the same thing . . . some kids can get past the visual and they’re into the abstract mode much quicker and then they don’t want to waste their time and be bored.”</p>

Figure 3. VHQMI Rubric: Mathematical Tasks.

2	Promotes “reform”-oriented aspects of tasks without specifying the nature of tasks beyond broad characterizations (e.g., “hands-on,” “real-world connections,” “higher order”), and without elaborating on their function in terms of providing opportunities for “doing mathematics” (Stein, Grover, & Henningsen, 1996; Smith & Stein, 1998). “Application” is characterized in terms of “real-world” context and/or students being active.	<p>“Hands-on activities, instead of doing worksheets . . . maybe build something or work it out with some kind of a model . . . the application of what they’ve learned is really important.”</p> <p>“Higher order thinking problems with application.”</p> <p>“Bring in the outside world to try to get the kids engaged.”</p> <p>“Not doing straight book work” (instead, “cutting out puzzle pieces and making two puzzles to prove Pythagorean’s Theorem”).</p> <p>Tasks should include “time to move and use those manipulatives and things.”</p>
1	Emphasizes tasks that provide students with opportunity to practice a procedure before then applying it conceptually to a problem (Hiebert et al., 1997).	<p>“First is to understand what the concept is, and what the formula is, and how to do it in terms of the numerical way. Second is applying it . . . if it’s put into a word problem.”</p>
0	Either (a) does not view tasks as inherently higher or lower quality or (b) does not view tasks as a manipulable feature of classroom instruction.	<p>(a) Depends on the teacher, “whatever works for them”; “Depends on the class”; “The thing that actually gets them to start asking questions.”</p> <p>(b) “We’re supposed to be using the CMP book which is pretty much, this is what you do and here’s what the teacher should say and it even tells you how it should run.”</p>

Figure 3. VHQM Rubric: Mathematical Tasks. (Continued)

Level	Description	Example(s)
2	Specifies WHAT students should be doing, using typical reform language and focusing primarily on the organization/structure of the activity, without describing the nature of classroom activity in content-specific ways (i.e., describes a “nontraditional” classroom, full of activity, but does not specify how the activity is specific to mathematics). If reasons WHY particular forms of activity are important are provided, they are not in terms of supporting students’ participation in doing mathematics.	<p>“The majority of the kids engaged in thinking and doing investigation, switching from traditional teaching to inquiry based.”</p> <p>“Students should be up moving around using manipulatives.”</p> <p>“Students should be up presenting.”</p> <p>Students should be doing “investigations, experiments . . . making their own graphs and comparing them with people at their tables, where they’re actually doing stuff together. They’re not just taking notes.”</p>
1	Stresses the importance of students being engaged and “on-task,” either taking for granted the quality of classroom activity (i.e., students should be doing whatever the teacher asked), or specifying traditional classroom activities as what should take place. Response either (a) stresses THAT students should be engaged and participating in classroom activities (i.e., on-task, paying attention), without specifying WHAT those activities should be, or (b) describes nature of classroom activity as traditional classroom activity.	<p>(a) “Student engagement . . . if students are working and actively participating”; “I think that being able to see that everybody is on task and hearing the questions that the teacher asks and listening to the students’ responses, I can tell from there just from that if they really understand what’s going on.”</p> <p>(b) “Student engagement . . . they’re participating and writing down what they need to be, taking notes, listening or appear to be listening. I mean not sleeping, not getting up and walking around the room. They’re in their seats, they’re working as a group, you know or maybe they’re working in groups, maybe they’re not, but you know they seem to be focused.”</p>

Figure 4. VHQM Rubric: Student Engagement in Classroom Activity

APPENDIX G: VIEWS OF STUDENTS' MATHEMATICAL CAPABILITIES RUBRICS

Table 3. Abbreviated Version of Coding Scheme to Assess the Nature of Teachers' Explanations Regarding the Source(s) of Students' Difficulties in Mathematics

Code and Definition	Example of Coded Transcript
<p>PRODUCTIVE Student performance (e.g., failure, success, engagement, interest) is described as a relation between student(s) and instructional and/or schooling opportunities.</p>	<p>Interviewer: So, in your own classroom when students don't learn as expected, what do you usually find are the reasons? Teacher: Why a kid didn't learn? Because I didn't make him. Interviewer: How do you make a kid learn? Teacher: I don't know. That's always the problem, isn't it? I, I do, and also again I, I might be different on that, but I, I really feel like if a kid's not learning in a classroom, it's my fault. That it's something that I'm not doing. There has to be a reason. I mean, I, you know, especially in the 8th grade, I mean, they can learn something. There is, there's something they can be doing. There's some way they can be doing it. And so, I mean, if a kid's just flat out not learning then there's something that I need to do better to make him learn and I don't always know what that is, but I mean, I do put most of the emphasis back on me.</p>
<p>MIXED Participant wavers between explaining student performance (e.g., failure, success, engagement, interest) 1) as a relation between student(s) and instructional and/or schooling opportunities and 2) as due to an inherent property of students (e.g., students are lazy) and/or as produced in relation to something other than instructional opportunities (e.g., parents don't value education, therefore students don't).</p>	<p>Interviewer: In your classrooms, when the students do not learn as expected, what do you find are the typical reasons? Teacher: Probably me...I don't put blame on the students. I mean, I think it's a combination. They have to do their part, and I have to do mine, so if they're not getting it, it may, and this, this may not be the best way, but I'll be honest, I look to the students that are consistently successful, and if they don't understand something, I know I'm doing something wrong, so I need to go back, and I need to think it through again or come up with a different strategy or a way of showing them to do the problem. You know, if it's a kid that is consistently off task and playing around or something, then I might just kind of think that, "Well, they're not paying attention," so, it's just kind of like what the majority of the class is doing, and I kind of judge off that.</p>

Code and Definition	Example of Coded Transcript
<p>UNPRODUCTIVE Student performance (e.g., failure, success, engagement, interest) is attributed to an inherent property of students (e.g., students are lazy) and/or as produced in relation to something other than instructional and/or schooling opportunities (e.g., parents don't value education, therefore students don't). Explanation presents students' mathematical capabilities as relatively stable (i.e., they are unlikely to change).</p>	<p>Interviewer: So what are some of the major challenges ... of teaching mathematics in this school?</p> <p>Teacher: The kids already don't want to learn math. They have this notion of not caring for it and usually it's instilled by their parent's cause their parents didn't get it, so they think it's okay that they didn't get it.</p>

Table 4. Abbreviated Version of Coding Scheme to Assess Teachers' Descriptions of How They Support Students Who Face Difficulties in Mathematics

Code and Definition	Example of Coded Transcript
<p>PRODUCTIVE</p> <p>Description of instructional actions one takes to support students who are facing difficulties are aimed at rigorous learning goals.</p> <p>Below is a list of instructional actions that are generally aimed at supporting students facing difficulty to participate in rigorous activity in the context of mainstream instruction. This is not an exhaustive list; the coder will need to make judgments regarding the nature of what participants describe.</p> <p><i>Pre-teach particular skills to students prior to mainstream instruction that are necessary for engaging in the targeted mathematical idea at a conceptual level; this is sometimes done in the context of a 2nd math class or intervention.</i></p> <p><i>Focus on how the task is introduced, or set-up. Ensure students are familiar with the context in a problem-solving scenario.</i></p> <p><i>Use tasks with multiple entry points.</i></p> <p><i>Focus on norms of participation.</i></p> <p><i>Assign competence to students (e.g., strategically mark students' contributions as important to attend to).</i></p> <p><i>Group students in ways that aim to maximize each student's participation (e.g., assigning roles, assigning near-peers).</i></p>	<p>Interviewer: In terms of ... having kids in the same room with a wide range of knowledge, what are like some of the strategies you use to address that ...?</p> <p>Teacher: One thing is [to] re-write the tasks from the books and</p> <p>Interviewer: From ... the [text] or?</p> <p>Teacher: Right. Trying to make sure that they maintain the rigor, but then ... are there multiple entry points into this particular task? Can I make sure that my student who struggles the most can find a way to engage in this task and my student who has the most skills in this classroom is still gonna be challenged?</p> <p>***</p> <p>Interviewer: [D]o you make changes within that class to provide different types of instruction?</p> <p>Teacher: ... I just make sure that there's lots of accountable talk, lots of group work. Making sure that kids are staying on task and it's been kind of a handful all year to get it going. I think I'm making some progress with them...</p> <p>Interviewer: Hmm hmm, so what do you do?</p> <p>Teacher: I keep the bar high. I have high expectations for them and I keep telling them that they can learn and they can be smart.</p>

Code and Definition	Example of Coded Transcript
<p>MIXED Clearly articulates learning goals and instructional supports for students who are facing difficulties that are aimed at rigorous activity however, some of what participant says indicates that some instructional actions are aimed at conventional learning goals. Supports typically aim at first ensuring that students develop “basic skills” before engaging in more rigorous activity.</p> <p>UNPRODUCTIVE Description of instructional actions one takes to support students who are facing difficulties are generally aimed at lowering the cognitive demand of activity (e.g., proceduralizing a task). Below is a list of instructional actions that are generally aimed at lowering the cognitive demand of activity. This is not an exhaustive list; the coder will need to make judgments regarding the nature of what participants describe.</p> <p><i>Remove any prompts that ask students to explain their thinking.</i></p> <p><i>Shorten problems.</i></p> <p><i>Show students how to complete a similar problem.</i></p> <p><i>Provide examples.</i></p> <p><i>“Drill,” “Use direct instruction.”</i></p> <p><i>Assign fewer problems.</i></p>	<p>Teacher: I’m always afraid to go ahead because I don’t feel my kids are mastering things and I try to challenge my kids and use a lot of word problems, use a lot of words and a lot of real world settings because that’s what they’re going to, you know, they’re not going to sit in some room doing a hundred adding fractions problems, but at the same time some of my kids actually need to do a hundred addition problems with fractions just so it sticks in their head that they’ve got to get a common denominator.</p> <p>Teacher: In the longer classes you can get a little bit more done but as far as the ability wise, there’s always going to be a class that can do more, so you going to give them more to chew on than you would the class that’s not quite capable.</p> <p>Interviewer: Okay so you would be adjusting, would you be adjusting the kind of tasks that you give them or would you be adjusting the pace or maybe how, how you would group the, the kinds of students? ...</p> <p>Teacher: ... [A] little bit of both. The ... pacing would be a little bit slower in the longer classes and then faster in the shorter classes. And then the, the tasks for the kids who are in the more capable classes they would get more independent practice where as the one in the less capable class they would get more modelling and guided practice.</p>

APPENDIX H: TAXONOMY OF TEACHERS' WORKGROUP CONVERSATIONS RUBRIC

Table 1. A Taxonomy of Learning Opportunities in Teachers' Meetings.

Category	Concepts developed	Mobilization for future work	Nature of discourse
Conflicting goals	No teaching concepts explicitly developed	No consensus about future instruction	Monological
Pacing	No teaching concepts explicitly developed	Pace of future instruction coordinated	
Logistics	No teaching concepts explicitly developed	Pace and topics of future instruction coordinated	
Tips and tricks	No teaching concepts explicitly developed	Instructional talk or activities for future instruction coordinated	
Collective interpretation, separate from future work	Analysis of instruction supports concept development	Analysis of instruction <i>not</i> linked to future work	Dialogical
Collective interpretation, linked to future work	Analysis of instruction supports concept development	Analysis of instruction linked to future work	

Note. Each category describes a meeting's prevailing conversational processes. The list is organized from the most limited learning opportunities to the richest, with the thick line separating the meetings that do not explicitly develop teaching concepts from those that do. Examples of each category are presented in subsequent sections.